# IONIZING RADIATION – 584

Conducted by

Division of Training and Manpower Development

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
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Pub Health

# CONTENTS

## ABSTRACT

This course is designed for professional health personnel as an introduction to the concepts of the radiological health field. The topical areas will include radiation sources, detection instruments, and control methods. Particular attention is given to the use of instruments and survey techniques. With this information, the student should be able to: 1) identify a radiation source, 2) select the proper instrument for evaluation of that source, and 3) recommend, if necessary, the appropriate control methods for personnel protection. The training course manual has been specially prepared for the trainees attending the course and should not be included in reading lists of periodicals as generally available.

**OBJECTIVES**

**BE ABLE TO USE A GEIGER COUNTER**

**OBSERVE RANGE OF ALPHA AND BETA PARTICLES**

**OBSERVE VARIATION OF GAMMA RADIATION WITH:**
**DISTANCE**
**ABSORBER MATERIAL TYPE**
**ABSORBER MATERIAL THICKNESS**
**INCIDENT ENERGY**

## A. INTRODUCTION

### 1. Objective

a. Be able to use a Geiger Counter.

b. Observe the range of alpha particles in air and the range of beta particles in aluminum.

c. Observe the variation of gamma radiation with:

1) source to detector distance

2) type of absorbing material

3) thickness of absorbing material

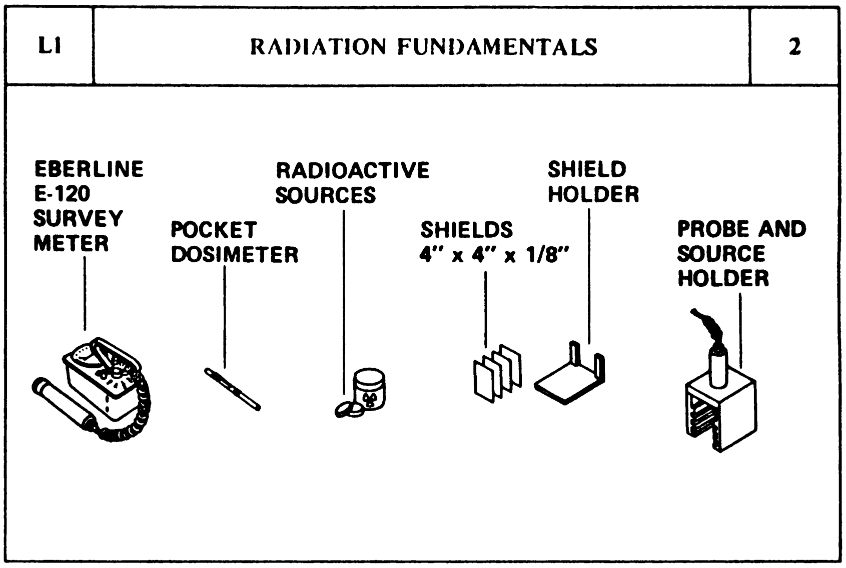
4) energy of incident gamma radiation

### 2. Overview

The instructor will begin the laboratory by stating the objectives, introducing the equipment and covering the precautions.

The demonstration-lecture contains a brief discussion of some radiation fundamentals. Next a Geiger Counter will be introduced and its controls, connectors and use explained.

The students during their laboratory will use the Geiger Counter to observe some fundamental properties of radiation. The range of alpha particles in air, and the range of beta particles in aluminum will be observed. Also the variation of gamma radiation with distance, absorber type, absorber thickness, and energy will be observed.




3. Equipment

a. Geiger Counter - Eberline E-120 with HP-190 hand probe,
Pocket Dosimeter - Victoreen 541A
Pocket Dosimeter Charger Victoreen 2000A
Film Badge, Finger Ring

b. Radioactive Sources

| | |
|---|---|
| 60 m Ci $Cs^{137}$ | .1 μ Ci $Sr^{90}$ |
| 30 m Ci $Co^{60}$ | .1 μ Ci $Am^{241}$ |
| .005 μ Ci $Tc^{99}$ | |

Note: The sources may be represented as $^{A}X$ or $X^{A}$.

c. Shields

4" X 4" X 1/8" Pb, A1, Fe

3" X 2" X .02" A1

d. Shield Holder

e. Probe and Source Holder

f. Masking Tape

g. Ruler

h. Lead Bricks

| L1 | RADIATION FUNDAMENTALS | 3 |
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**PRECAUTIONS**

AVOID DIRECT CONTACT WITH SOURCE

AVOID UNNECESSARY EXPOSURE

WEAR FILM BADGE, DOSIMETER AND
FINGER RING

4. Precautions

The above precautions will be observed during the demonstration-lecture and the students' laboratory exercise.

| L1 | RADIAITON FUNDAMENTALS | 4 |
|---|---|---|

**TYPES OF RADIOACTIVITY**
**STUDIED IN TODAY'S LAB**

1. ALPHA PARTICLES
2. BETA PARTICLES
3. GAMMA RAYS

B. INSTRUCTOR'S DEMONSTRATION-LECTURE

1. Types of Radioactive Emissions

a. Introduction

In this lab three types of radioactive emissions will be studied. These emissions are alpha particles, beta particles and gamma rays. These are not the only types of radioactive emissions, there are several other types.

| LI | RADIATION FUNDAMENTALS | 5 |
| --- | --- | --- |

**ALPHA PARTICLES**

1. LEAST PENETRATING
2. 2P + 2N – HELIUM NUCLEUS
3. HIGH PROBABILITY OF INTERACTION
4. LOSES ENERGY OVER SHORT DISTANCE
5. EMITTED MONOENERGETICALLY FOR A GIVEN RADIONUCLIDE

1. Types of Radioactive Emissions (contd)

   b. Alpha Particles

      Alpha particles are the least penetrating of the three types of radiation. They can be absorbed or stopped by a few centimeters of air or a thin piece of paper. They have an electric charge opposite to and exactly twice that of the electron, and a mass number of 4. Thus, an alpha particle and a helium nucleus are identical in structure. With a few exceptions, only relatively heavy radioactive nuclides decay by alpha emission.

      The alpha particle's large mass, its charge, and its high velocity tend to make it an efficient projectile when it encounters atoms of an absorbing material. In other words, it has a high probability of interacting, or colliding, with orbital electrons, and also atomic nuclei.

      Due to the high probability of interaction between an alpha particle and orbital electrons of an absorbing medium, a large number of ion pairs are formed per unit path length. Because a fraction of the kinetic energy of the alpha particle is absorbed on formation of each ion pair, this type of radiation loses its energy over a relatively short distance. For these reasons, the range of alpha particles is much less than the range of other forms of radiation. It is, in summary, a highly ionizing but weakly penetrating radiation.

      Alpha particles from a given radio-nuclide are all emitted with the same energy, consequently those emitted from a given source will have approximately the same maximum range in a material. Alpha particle range is usually expressed in centimeters of air.

| LI | RADIATION FUNDAMENTALS | 6 |
|---|---|---|

**BETA PARTICLES**

1. HIGH-SPEED ELECTRON
2. ORIGINATE IN NUCLEUS
3. RANGE IN AIR IS SEVERAL HUNDRED TIMES ALPHA PARTICLES
4. LOSES ENERGY BY IONIZATION, EXCITATION, AND BREMSSTRAHLUNG
5. EMITTED WITH VARYING ENERGY

1. Types of Radioactive Emissions (contd)

   c. Beta Particles

      Beta particles are negatively charged particles. They have the same mass and charge as an electron and can be considered high-speed electrons. They originate in the nucleus, in contrast with ordinary electrons, which exist in the orbits around the nucleus. They travel several hundred times the distance of alpha particles in air and require, depending upon the beta particle's energy, a few millimeters of aluminum to stop them. Beta activity can be expected where the n:p ratio is high.

      Normally a beta particle loses its energy in a large number of ionization and excitation events in a manner analogous to the alpha particle. Due to the smaller size and charge of the electron, however, there is a lower probability of beta radiation interacting in a given medium; consequently, the range of a beta is considerably greater than an alpha of comparable energy.

| LI | RADIATION FUNDAMENTALS | 6 |
|---|---|---|

**BETA PARTICLES**

1. HIGH-SPEED ELECTRON
2. ORIGINATE IN NUCLEUS
3. RANGE IN AIR IS SEVERAL HUNDRED TIMES ALPHA PARTICLES
4. LOSES ENERGY BY IONIZATION, EXCITATION, AND BREMSSTRAHLUNG
5. EMITTED WITH VARYING ENERGY

1. Types of Radioactive Emissions

c. Beta Particles (contd)

In addition to ionization and excitation, a beta may have an interaction with an atom which results in the production of x-rays. A high energy beta may penetrate through the electron cloud surrounding the nucleus of the atom, and in traveling through the various quantum energy states of the orbital electrons, it experiences the strong electrostatic force of the nucleus, resulting in a change in velocity and the emission of several x-rays having a spectrum of energies. (Such x-rays are referred to as "Bremsstrahlung radiation".) It becomes an increasingly important mechanism of energy loss as the initial energy of the beta increases, and the atomic number of the absorbing medium increases.

When betas are emitted, the total kinetic energy involved in the decay of the radioactive atom is divided between the beta and a neutrino. Therefore the beta may be emitted with an energy varying from practically zero up to a maximum energy (which is a characteristic of the particular radionuclide).

| LI | RADIATION FUNDAMENTALS | 7 |
|---|---|---|

GAMMA RAYS

1. ELECTROMAGNETIC RADIATION
2. INTERACTIONS
   - PHOTOELECTRIC EFFECT
   - COMPTON EFFECT
   - PAIR PRODUCTION

1. Types of Radioactive Emissions (contd)

d. Gamma Rays

Gamma rays are a type of electromagnetic radiation and move with the speed of light. The basic difference between gamma rays and x-rays is their source; gamma rays originate in the nucleus, x-rays in the orbital electron structure. The basic difference between gamma rays and visible light is their frequency.

Gamma rays are basically distortions in the electromagnetic field of space, and because of this fact, they interact electrically with atoms to produce ionization even though they themselves possess no net electrical charge.

| LI | RADIATION FUNDAMENTALS | 7 |
|---|---|---|

GAMMA RAYS

1. ELECTROMAGNETIC RADIATION
2. INTERACTIONS
   PHOTOELECTRIC EFFECT
   COMPTON EFFECT
   PAIR PRODUCTION

1. Types of Radioactive Emissions

   a. Gamma Rays (contd)

There are three mechanisms by which gamma rays lose energy by interacting with matter; the photoelectric effect, the Compton effect and pair production.

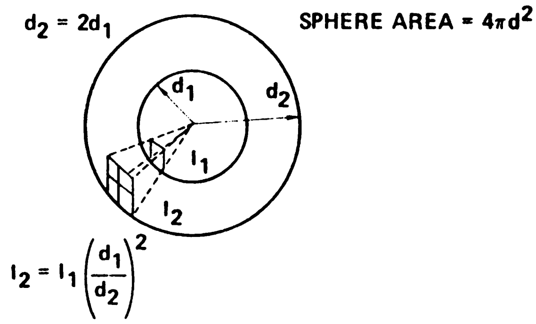
The photoelectric effect is an all-or-none energy loss. The gamma wave, or photon, imparts all of its energy to an orbital electron of some atom.

The Compton effect provides a means of partial energy loss for the incoming gamma ray. Again the gamma ray appears to interact with an orbital electron of some atom, but in the case of Compton interactions, only a part of the energy is transferred to the electron, and the gamma ray proceeds with less energy. By this mechanism of interaction, the direction of photons in a beam may be changed, so that scattered radiation may appear around corners and behind "shadow" type shields.

Pair production, the third type of interaction, is much rarer than either the photoelectric or Compton effect. In fact, pair production is impossible unless the gamma ray possesses at least 1.02 MeV of energy. (Practically speaking, it does not become important until two MeV of energy). In pair production a gamma photon simply disappears in the vicinity of a nucleus, and in its place appears a pair of electrons--one negative, one positive.

| | | |
|---|---|---|
| L1 | RADIATION FUNDAMENTALS | 8 |

**INVERSE SQUARE LAW**



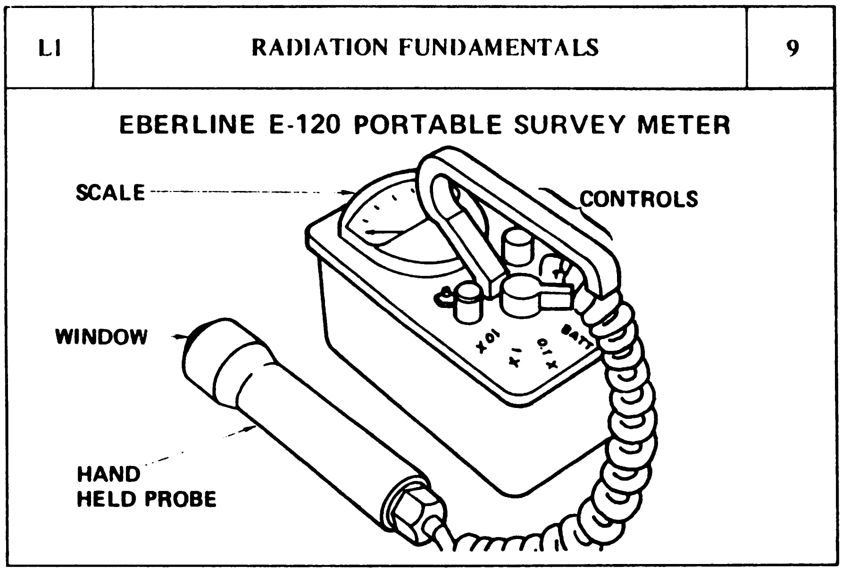

2. Variation of Radiation with Distance

Radiation generally obeys the inverse square law. At distances, d, far enough from the source so that the source appears small (or as a point), the intensity, I, decreases according to

$$I_2 = I_1\left(\frac{d_1}{d_2}\right)^2$$

which is the inverse square law. $I_1$ is the intensity at distance $d_1$, and $I_2$ is the intensity at $d_2$.

This can be seen from a consideration of a point source emitting radiation in all directions, that is toward the surface of a sphere surrounding the point source. Because the total radiated energy from a source gets spread out over larger areas, and the area increases as the distance squared, the energy per unit area decreases as the inverse distance squared.




3. Laboratory Equipment

a. Introduction to a Geiger Counter

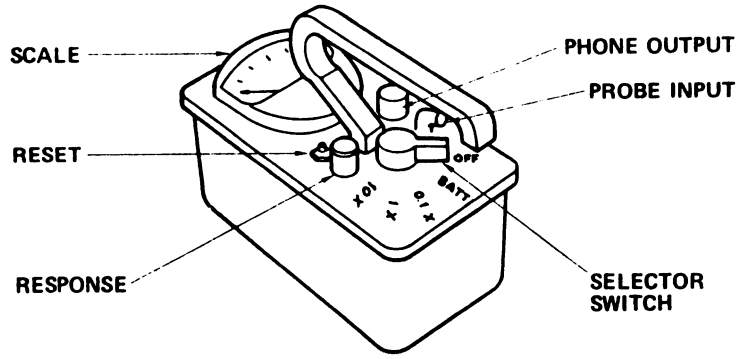
The Eberline Model E-120, shown in Figure 9, is a small, light-weight Geiger counter used for the detection and measurement of alpha, gamma and beta radiation with an external hand probe.

The radiation intensity is read out on a large meter with a linear scale. Three switch-selected ranges give varying scale sensitivities. The response time of the meter is continuously adjustable, and the reading may be brought to zero at any time by the reset control. Two "D" size batteries power the instrument.

A phone output is provided for the use of earphones, a speaker, or for using an event counting device called a scaler.

| L1 | RADIATION FUNDAMENTALS | 10 |
| --- | --- | --- |

**EXTERNAL CONTROLS OF THE EBERLINE E-120 PORTABLE SURVEY METER**




3. Laboratory Equipment (contd)

b. Controls and Connectors of the Geiger Counter

As shown in Figure 10 the five position selector switch turns the instrument OFF, checks the BATTery condition and selects scale multipliers of X0.1, X1 or X10. This number must be multiplied by the meter reading to obtain the correct exposure or count rate. Response time of the meter is adjusted to the most desirable compromise between speed and fluctuation by using the response control. The reset button discharges the integrating capacitor, and brings the meter reading rapidly to zero. The scale is marked in Counts Per Minute (CPM) and milliroentgen per hour (mR/hr). The CPM scale is divided from 0-7K CPM in 35 increments and the mR/hr scale is divided from 0-5 in 25 increments.

| L1 | RADIATION FUNDAMENTALS | 11 |
|---|---|---|

**USING THE GEIGER COUNTER**

1. CHECK FOR PHYSICAL DAMAGE AND CONNECT PROBE TO INSTRUMENT
2. CHECK BATTERY BY TURNING SELECTOR SWITCH TO BATT POSITION
3. USE CHECK SOURCE
4. MOVE SELECTOR SWITCH TO OBTAIN AN UPSCALE READING
5. ADJUST RESPONSE CONTROL FOR DESIRED RESPONSE

4. Laboratory Equipment (contd)

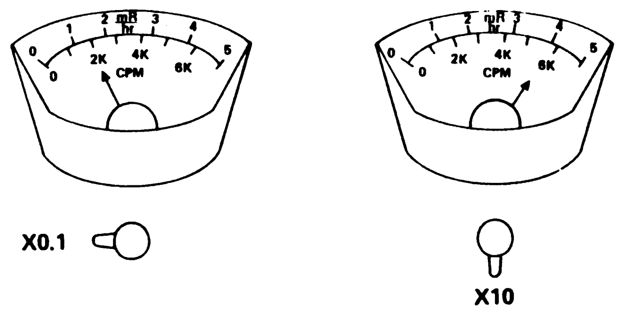
c. Using the Geiger Counter

Before making measurements the instrument should be checked for physical damage. Connect the probe cable to the angle probe connector on the instrument panel (if the probe cable has not already been connected). To start the instrument turn the selector switch to the BATTery check position. The meter should indicate within the BATT OK area. Having determined that the battery is good and prior to any measurements, the instrument should be checked to insure that it is operating properly. An operation check is made by placing a check source, in this case a .005μ Ci $Tc^{99}$ beta emitter, in a repeatable position adjacent to the detector (see Figure 14). Move the selector switch to a range that gives an upscale reading. The instrument should give approximately the same check source reading each time the instrument is used. Care must be taken to insure that the source and detector are in the same repeatable positions each time the check is made. The reading of the check source should be recorded for future reference.

Pushing the Reset button while the check source is in position will cause the meter to drop to zero rapidly, then climb back to source reading when the reset is released. The Response may be adjusted to get the most desirable compromise between speed of response and meter fluctuation.

| L1 | RADIATION FUNDAMENTALS | 12 |
|---|---|---|

**READING THE SCALES**




**2K CPM X.1 = 200 CPM** **4 mR/HR X10 = 40 mR/HR**

3. Laboratory Equipment (contd)

   d. Reading the Geiger Counter Scales

   The meter reading must be multiplied by the scale indexed by the rotary switch in order to obtain the proper number. For example, if the meter reading was 2K CPM (K=1000) and the rotary switch was indexing the X.1 range, the correct count rate would be 2K CPM multiplied by .1 or 200 counts per minute. If exposure rate was being measured instead of count rate and the meter read 4 mR/hr with a X10 multiplier the reading would be 4 multiplied by 10 mR/hr or 40 mR/hr.

| L1 | RADIATION FUNDAMENTALS | 13 |
|---|---|---|

STUDENTS' LABORATORY EXERCISE

1. STUDY PENETRATING ABILITY OF ALPHA, BETA AND GAMMA RADIATION
2. OBSERVE VARIATION OF GAMMA RADIATION WITH ABSORBER TYPE, ABSORBER THICKNESS AND INCIDENT ENERGY

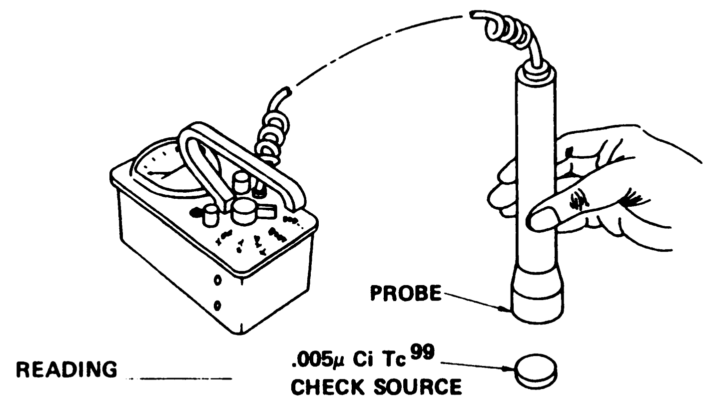
## C. STUDENTS' LABORATORY EXERCISE

### 1. Introduction

During the laboratory session the students will have the opportunity to observe some properties of nuclear radiation. They will observe the penetrating ability of alpha, beta and gamma radiation, by allowing these radiations to pass through different media. They will also observe the variation of gamma radiation with absorber type, absorber thickness and incident energy.

| LI | RADIATION FUNDAMENTALS | 14 |
|---|---|---|

**USE OF CHECK SOURCE**




2. Fundamentals of Nuclear Radiation

   a. Geiger Counter Operational Check Out

      1) Turn on the G-M survey meter and check the battery by turning the selector switch to BATT. Wait at least 30 seconds for the system to reach stability.

      2) Place the .005 μ Ci $Tc^{99}$ checksource in front of the probe window. Turn the range selector switch to the least sensitive scale, (highest). If there is no reading, turn the range selector switch to the middle range first, and then to the most sensitive range, (lowest).

         Note if there is any indication of normal background. (Normal backgound is usually around 0.2 mR/hr or 20 counts/minute, randomly spaced.) The counts may be heard with headphones which can be attached to the instrument.

      3) Record the check source reading on the form provided.

      4) When the laboratory has been completed turn the control dial to the OFF position.

| LI | RADIATION FUNDAMENTALS | 15 |
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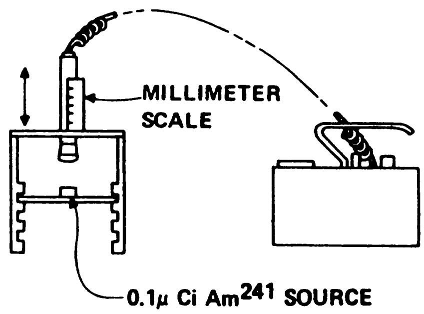
**EXPERIMENTAL SET-UP FOR RANGE OF APLHA PARTICLES IN AIR**




2. Fundamentals of Nuclear Radiation (contd)

b. Passage of Alpha Particles Through Air

1) Set up the Geiger Counter and .1 μ Ci $Am^{241}$ Alpha source as shown in Figure 15.

2) Set the selector switch so that a mid-scale reading is obtained.

3) Interpose a thin sheet of paper between the source and detector. What effect does this have on the observed count rate? Record data on Figure 16.

4) Adjust the detector so that the probe window is 5mm from the alpha source. Place a pencil mark on the probe barrel coinciding to the zero position on the millimeter scale. Note the count rate.

5) Withdraw the probe in several steps. Note the position and count rate for each position. Record data on Figure 16.

6) Plot data corrected for $1/r^2$ on Figure 17. The correction factor (CF) is the millimeter scale reading(s) + 5mm, this quanity squared all divided by $25mm^2$. That is $CF = \frac{(s + 5)^2}{25mm^2}$. What is the distance in air that the $Am^{241}$ alpha's travel? (This distance is low due to alpha absorption in the probe window). What can you deduce regarding energy of alpha emission?

## SHIELDING OF ALPHA PARTICLES USING PAPER

SOURCE____________________

INITIAL READING ________________________

READING AFTER INTERPOSITION OF PAPER ______________________

## PASSAGE OF ALPHA PARTICLES THROUGH AIR

| SCALE READING S (mm) | SOURCE TO DETECTOR DISTANCE S + 5 (mm) | METER READING (CPM) | $1/r^2$ CORRECTION CF | CORRECTED READING CPM x CF |
|---|---|---|---|---|
| | | | | |
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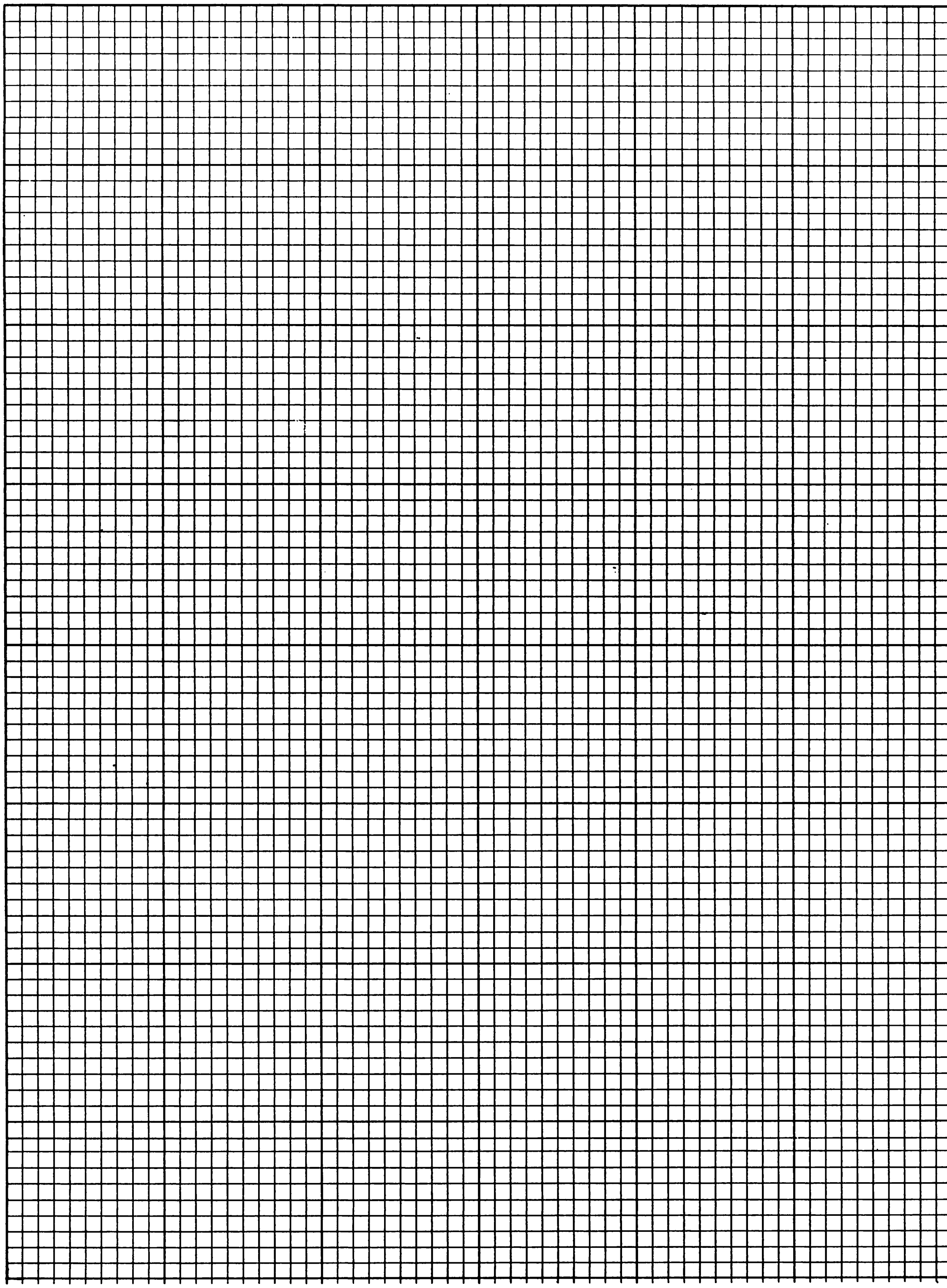
## PASSAGE OF ALPHA PARTICLES THROUGH AIR



RANGE (mm)

CORRECTED (CPM)

| L1 | RADIATION FUNDAMENTALS | 18 |
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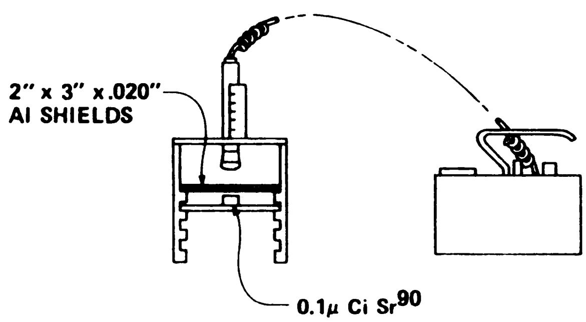
EXPERIMENTAL SET-UP FOR RANGE OF BETA PARTICLES IN ALUMINUM




2. Fundamentals of Nuclear Radiation (contd)

c. Passage of Beta Particles Through Aluminum

1) Set up the Geiger Counter and .1 μ Ci $Sr^{90}$ source as shown in Figure 18.

2) Set the selector switch so that a mid-scale reading is obtained. Record data on Figure 19.

3) Interpose one of the 20 mil aluminum shields. Again note and record the count rate.

4) Continue adding foils until the count rate is reduced to normal background count.

5) Plot the data of Figure 19 on Figure 20. What is the range of $Sr^{90}$ beta particles in aluminum? What can you deduce regarding the energy of beta particle emission?

| PASSAGE OF BETA PARTICLES THROUGH ALUMINUM | |
|---|---|
| NUMBER OF 20 MIL Al SHIELDS | METER READING (CPM) |
| | |
| | |
| | |
| | |
| | |
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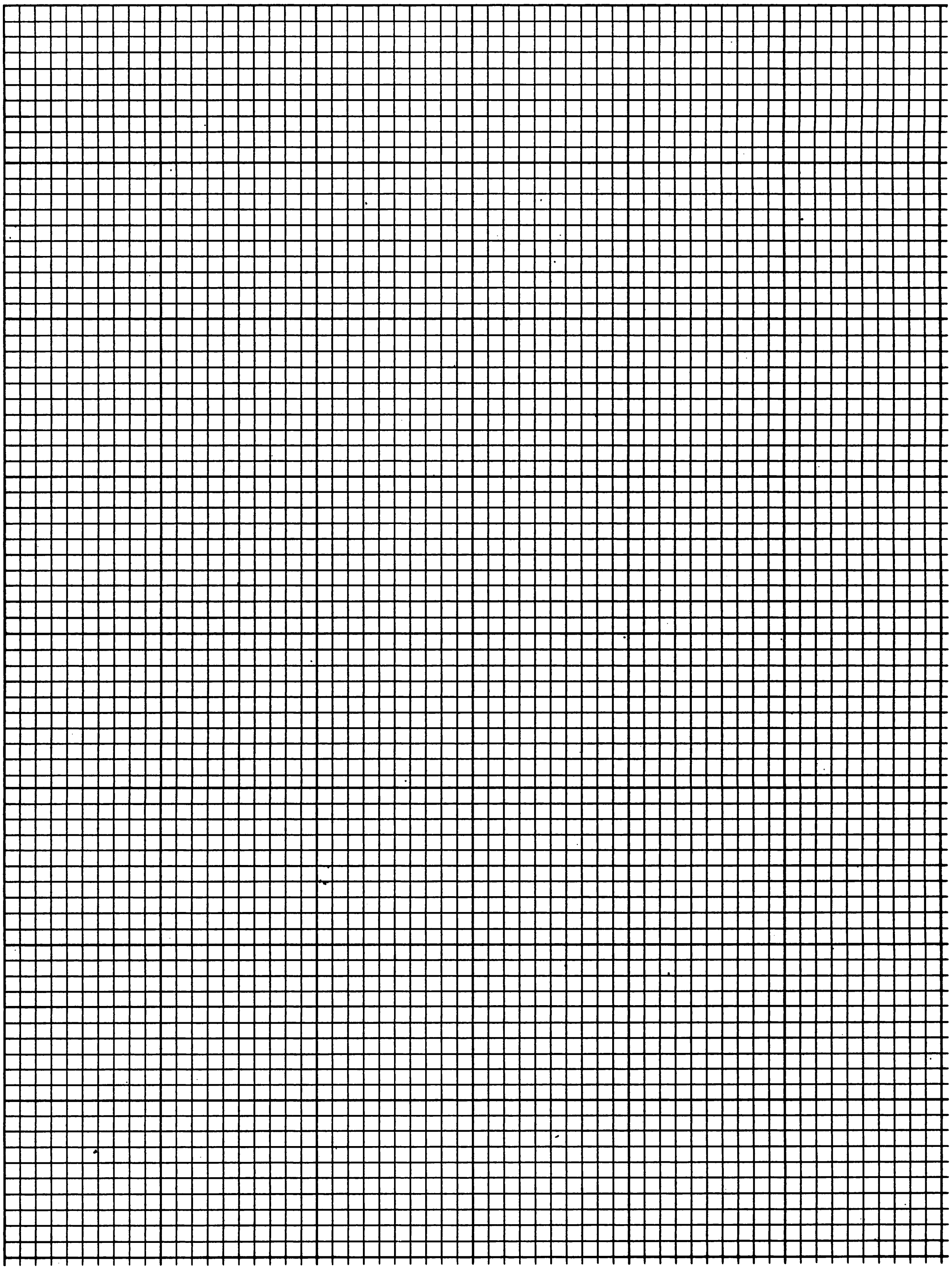
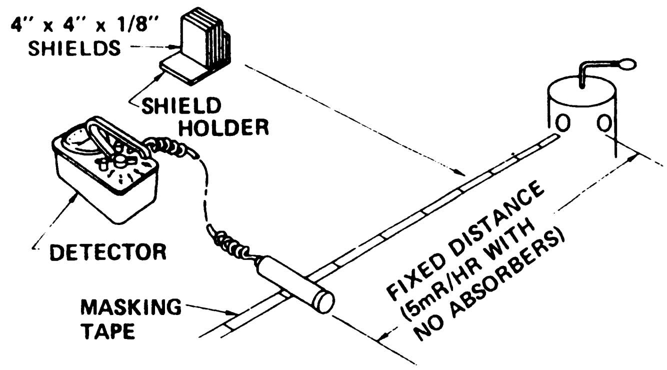
| | |
| | |
| | |
| | |
| | |
| SOURCE | |

## PASSAGE OF BETA PARTICLES THROUGH ALUMINUM



| LI | RADIATION FUNDAMENTALS | 21 |
|---|---|---|

EXPERIMENTAL SET-UP FOR GAMMA RADIATION




2. Fundamentals of Nuclear Radiation (contd)

   d. Passage of Gamma Rays Through Different Absorbing Materials

      1) Set the equipment up as shown in Figure 21. Turn survey meter on least sensitive scale.

      2) Set meter at a distance from the source so that a reading of 5 mR/hr is observed. Interpose 2.5 inches of lead between counter and source. Reduce sensitivity of meter until a reading (∿ midscale) is obtained and record reading on Figure 22

      3) Reduce lead shield thickness by .5 inches to 2.0 inches. Make a reading and record result on Figure 22.

      4) Repeat the above procedure for five thicknesses of iron and aluminum shielding (2.5, 2.0, 1.5, 1.0, 0.5 inches).

      5) Divide the exposure rate at a given absorber thickness by the exposure rate of zero absorber thickness for each of the materials used. The data will be plotted on Figure 23.

      6) Perform steps 1-5, but with a $Cs^{137}$ source instead of $Co^{60}$ source. Data is to be recorded on Figure 24 and plotted on Figure 25.

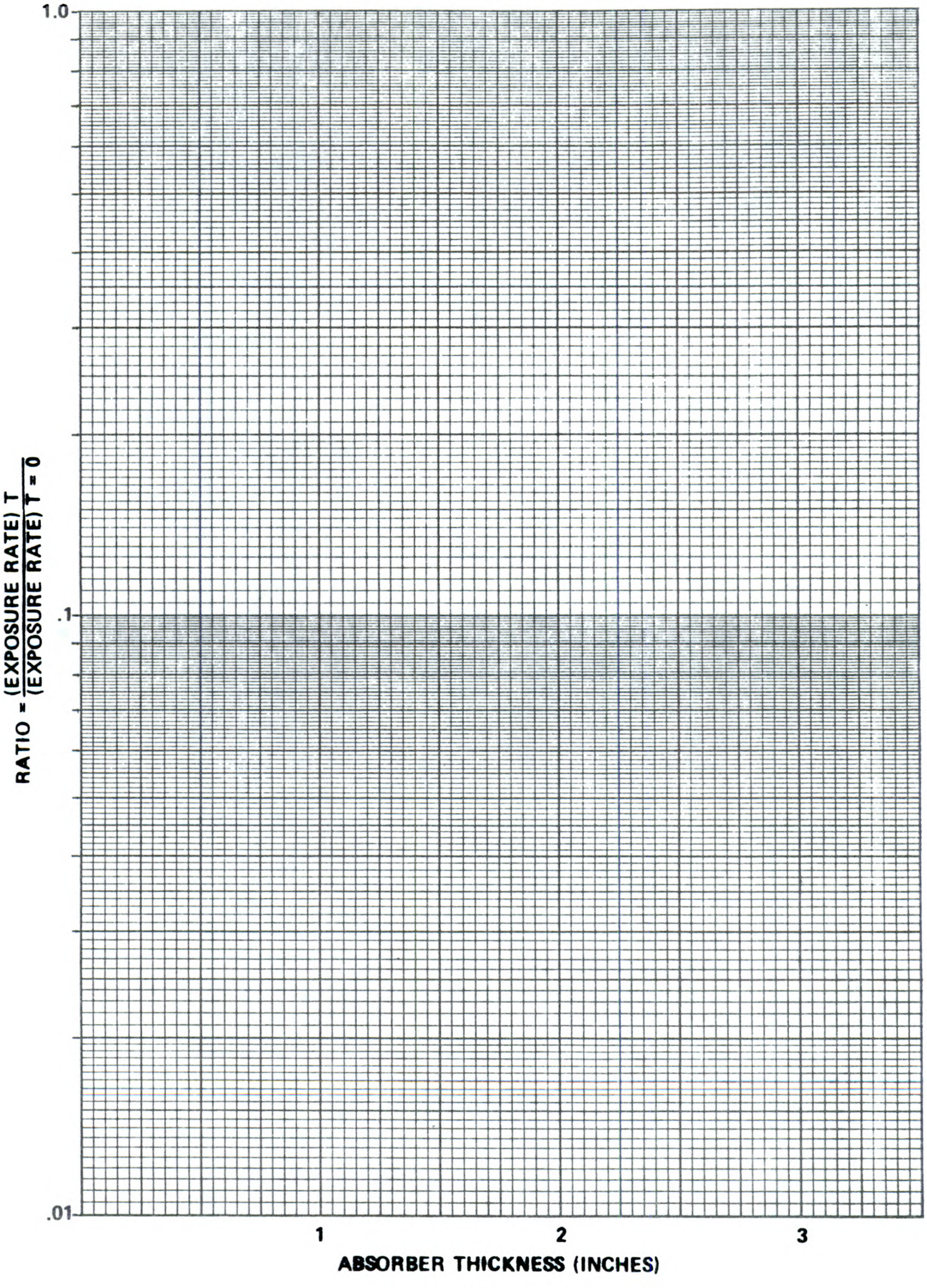
      7) What qualitative statement can you make regarding the Z (atomic number) of an absorber and its affect on gamma radiation? What is the effect of reducing incident gamma energy?

PASSAGE OF Co 60 GAMMA RAYS THROUGH DIFFERENT ABSORBING MATERIALS

ABSORBER THICKNESS (INCHES)

| T | ALUMINUM | | IRON | | LEAD | |
|---|---|---|---|---|---|---|
| INCHES | mR/HR AT T | (mR/HR) AT T / (mR/HR) AT T = 0 | mR/HR AT T | (mR/HR) AT T / (mR/HR) AT T = 0 | mR/HR AT T | (mR/HR) AT T / (mR/HR) AT T = 0 |
| 0 | | | | | | |
| 0.5 | | | | | | |
| 1.0 | | | | | | |
| 1.5 | | | | | | |
| 2.0 | | | | | | |
| 2.5 | | | | | | |

PASSAGE OF $Co^{60}$ GAMMA RAYS THORUGH
DIFFERENT ABSORBING MATERIALS

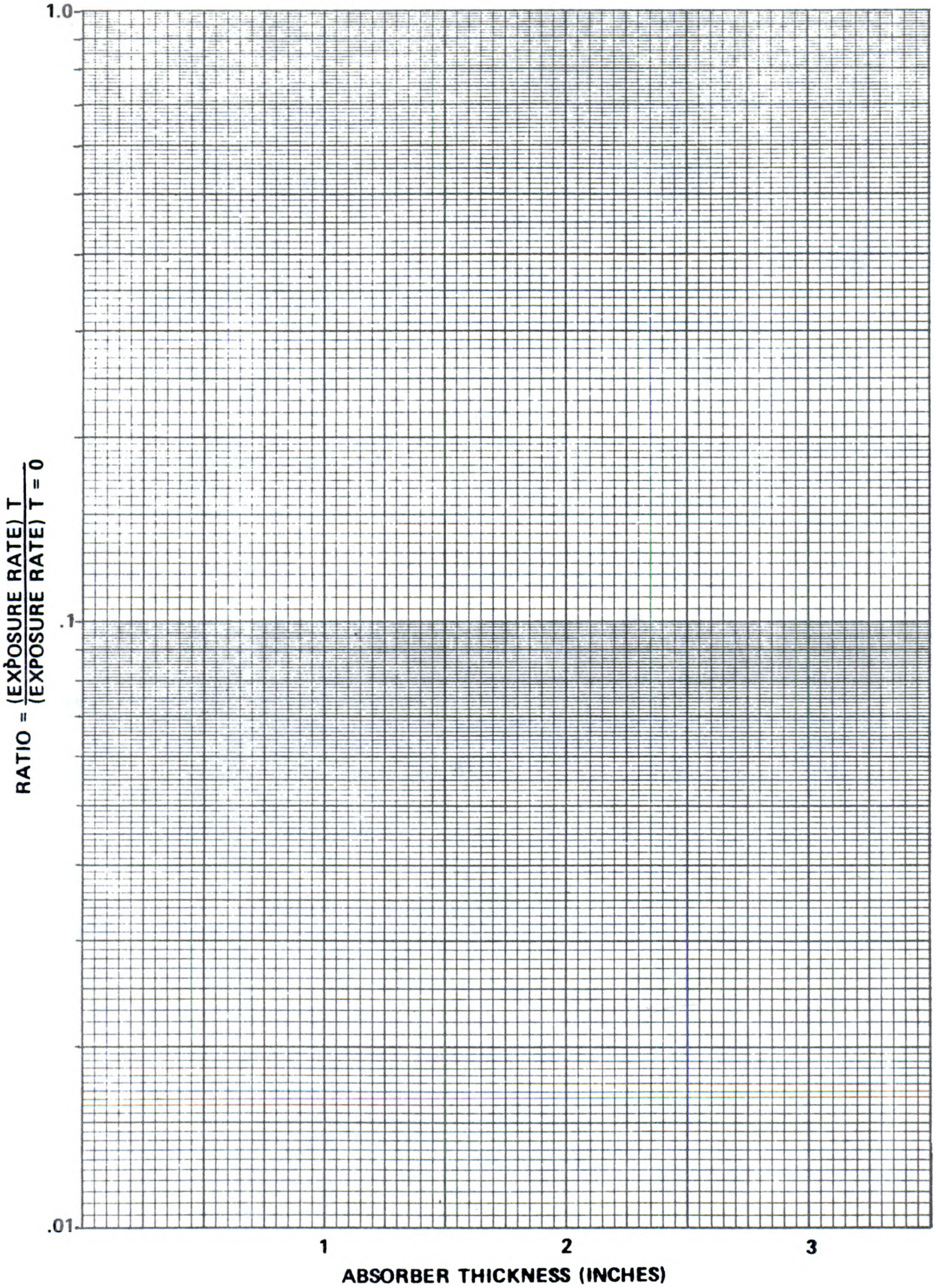


PASSAGE OF Cs 137 GAMMA RAYS THROUGH
DIFFERENT ABSORBING MATERIALS

ABSORBER THICKNESS (INCHES)

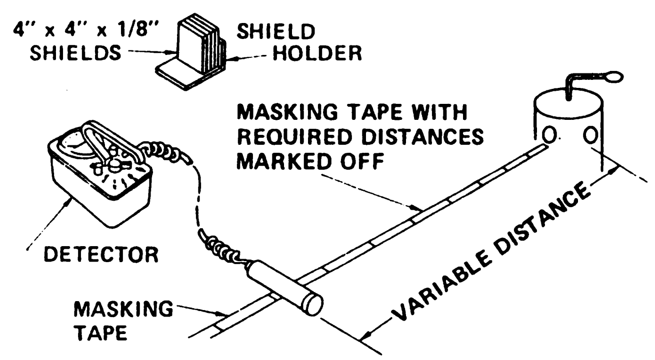
| T | ALUMINUM | | IRON | | LEAD | |
|---|---|---|---|---|---|---|
| INCHES | mR/HR AT T | (mR/HR) AT T / (mR/HR) AT T = 0 | mR/HR AT T | (mR/HR) AT T / (mR/HR) AT T = 0 | mR/HR AT T | (mR/HR) AT T / (mR/HR) AT T = 0 |
| 0 | | | | | | |
| 0.5 | | | | | | |
| 1.0 | | | | | | |
| 1.5 | | | | | | |
| 2.0 | | | | | | |
| 2.5 | | | | | | |

PASSAGE OF $Cs^{137}$ GAMMA RAYS THROUGH DIFFERENT ABSORBING MATERIALS



| L1 | RADIATION FUNDAMENTALS | 26 |
|---|---|---|

**EXPERIMENTAL SET-UP FOR GAMMA RADIATION**




2. Fundamentals of Nuclear Radiation (contd)

   e. Variation of Exposure with Detector-Source Distances and Lead Sheild Thickness

      1) Set up equipment as shown in Figure 26. Turn on survey meter, set meter on least sensitive scale.

      2) Set meter at 8 feet from the $Cs^{137}$ source and interpose 8 layers of lead shielding.

      3) Reduce sensitivity of meter scale until a $\sim$ midscale reading is obtained and record reading on Figure 27.

      4) Move meter to 6 feet from source. Repeat step 3.

      5) Move meter to 4 feet from source. Repeat step 3.

      6) Continue in this manner for each thickness of lead shielding, (i.e., 8, 4, and 0 layers) taking readings at each distance 8, 6, and 4 feet to complete figure 27.

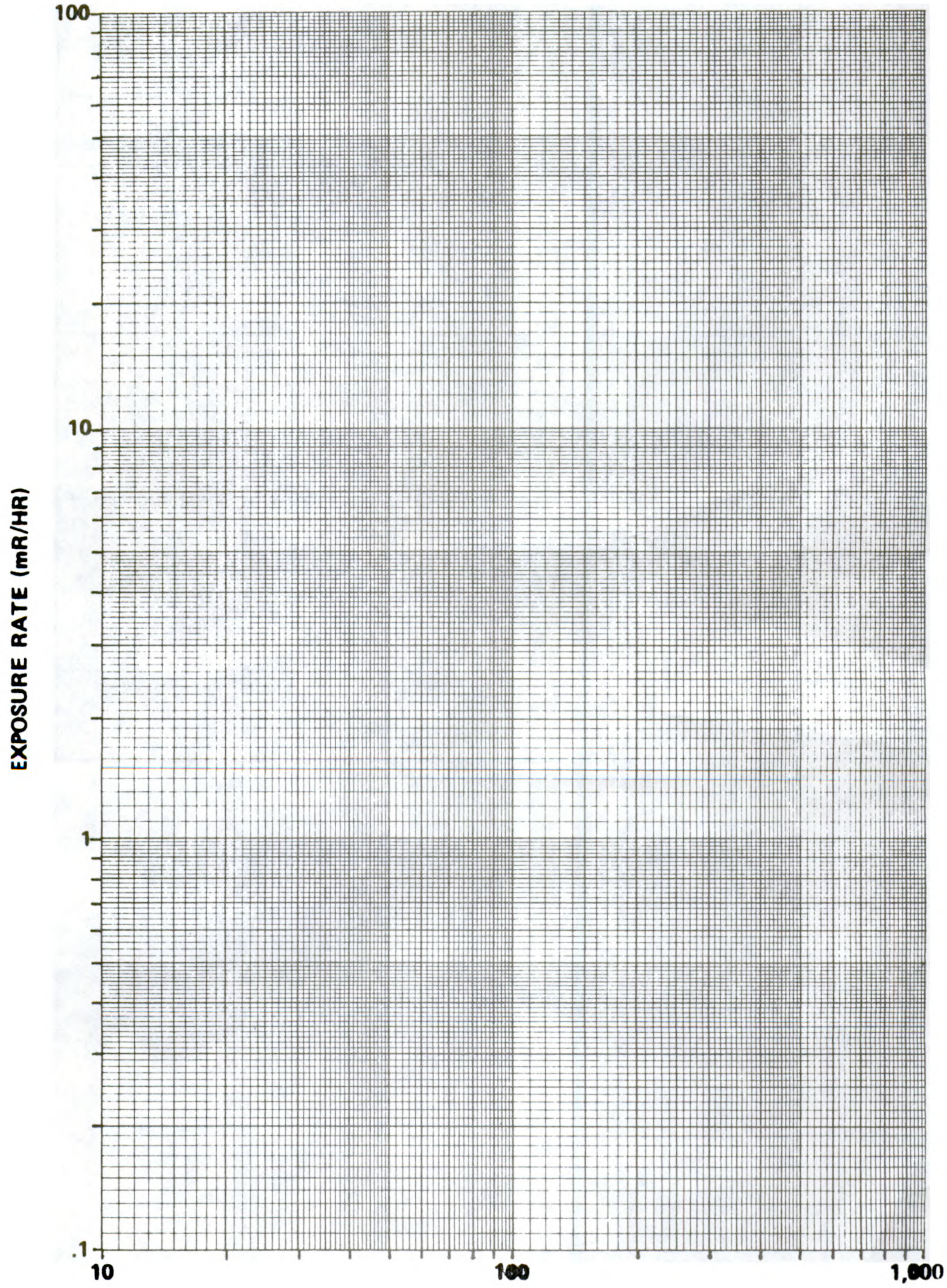
      7) Data from Figure 27 is to be plotted on Figure 28.

      8) What effect on exposure rate does doubling the distance have?

## VARIATION OF EXPOSURE RATE WITH DISTANCE AND ABSORBER THICKNESS

| DISTANCE | 1/8TH INCH LAYERS LEAD | | |
|---|---|---|---|
| | 0 | 4 | 8 |
| 4 | | | |
| 6′ | | | |
| 8′ | | | |
| SOURCE | | | |

## VARIATION OF EXPOSURE RATE WITH DISTANCE AND ABSORBER THICKNESS



# CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS
# LABORATORY NO. 2

COURSE OUTLINE

II. CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS

A. INTRODUCTION

1. Objectives

2. Overview

3. Equipment

4. Precautions

B. INSTRUCTOR'S DEMONSTRATION - LECTURE

1. Introduction

2. Composite Characteristic Curve for Ionization Detectors

3. Detectors Based on Composite Characteristics Curve

4. Laboratory Equipment

a. Pocket Dosimeter

b. Cutie Pie Ionization Chamber

c. Geiger Counter

d. Mini Pulser

C. STUDENTS' LABORATORY EXERCISE

1. Introduction

2. Use of a Pocket Dosimeter, Cutie Pie Ionization Detector and Geiger Counter

a. Pocket Dosimeter

b. Cutie Pie Calibration

c. Measuring Radiation Intensities Using the Cutie Pie

d. Calibration of a Geiger Counter to CPM Units

e. Measuring Radiation Intensities Using the Geiger Counter

## OBJECTIVES

**KNOW THE CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS.**

**BE ABLE TO USE A POCKET DOSIMETER.**

**BE ABLE TO CALIBRATE AND USE A CUTIE PIE IONIZATION CHAMBER AND A GEIGER COUNTER.**

## A. INTRODUCTION

### 1. Objectives

a. Know the characteristics of ionization chambers and Geiger counters.

b. Be able to use a pocket dosimeter.

c. Be able to calibrate and use a cutie pie ionization chamber and a Geiger counter.

### 2. Overview

The instructor will begin the lab by stating the objectives, introducing the equipment and covering the precautions.

The demonstration lecture begins with a discussion of the composite characteristics curve for ionization detectors. Following this discussion a pocket dosimeter, cutie pie ionization chamber and a Geiger counter will be discussed. Characteristics and use of these instruments will be covered in detail.

During the students' laboratory exercise the students will use a pocket dosimeter, a cutie pie ionization chamber and a Geiger counter. The cutie pie and Geiger counter will be calibrated and their use in making exposure rate measurements compared.

The lab will be submitted to the instructor at the completion of the laboratory.

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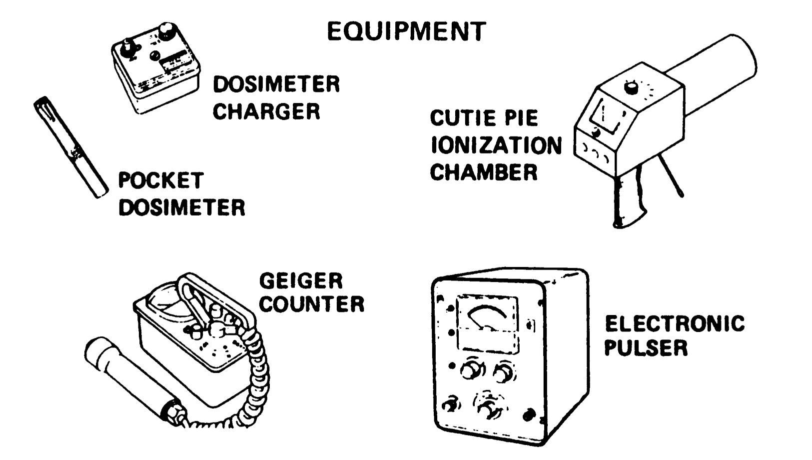
| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 2 |




3. Equipment List

   a. Pocket Dosimeter - Victoreen Model 541A
      Pocket Dosimeter Charger - Victoreen Model 2000A
      Film Badge, Finger Ring

   b. Cutie Pie Ionization Chamber - Technical Associates CP-5

   c. Geiger Counter - Eberline E-120 with HP-190 Hand Probe.

   d. Electronic Pulser - Eberline MP-1.

   e. Radioactive Sources

      60 m Ci $Cs^{137}$

      30 m Ci $Co^{60}$

   f. Large Lead Shields

Note: The sources may be represented as $^{A}X$ or $X^{A}$.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 3 |
|---|---|---|

**PRECAUTIONS**

DO NOT DIRECTLY TOUCH A RADIOACTIVE SOURCE.

AVOID UNNECESSARY EXPOSURE.

WEAR A FILM BADGE, FILM RING AND POCKET DOSIMETER AT ALL TIMES DURING THE LAB SESSION.

4. Precautions

These precautions will be followed during the demonstration and during the students' laboratory exercise.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 4 |
|---|---|---|

**BASIC DETECTOR ELEMENTS**

- **SENSING ELEMENT**
  - **ION COLLECTING**
  - **NON-ION COLLECTING**
- **INDICATING ELEMENT**

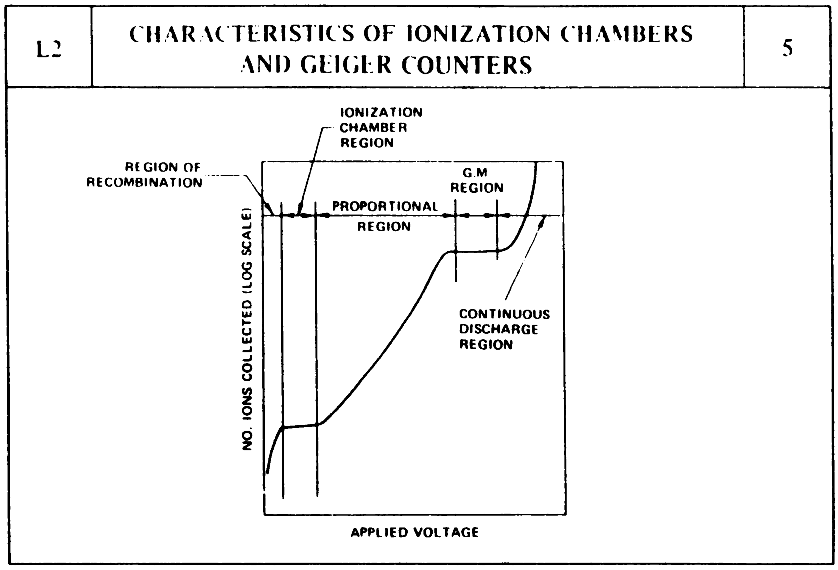
B. INSTRUCTOR'S DEMONSTRATION - LECTURE

1. Introduction

Instrumentation used for detecting radiation requires two basic elements - a sensing element and an indicating element. Sensing elements convert the energy of radiation into electrical energy. From the sensing element the electrical energy (which may pass through intermediate electronic circuits) is registered on an indicating element, for example, a meter.

Sensing elements for the detection of radiation are dependent on the formation of ions for their operation. These sensing elements can be divided into two broad categories - those which depend upon the collection of these ions and those which do not depend upon ion collection.

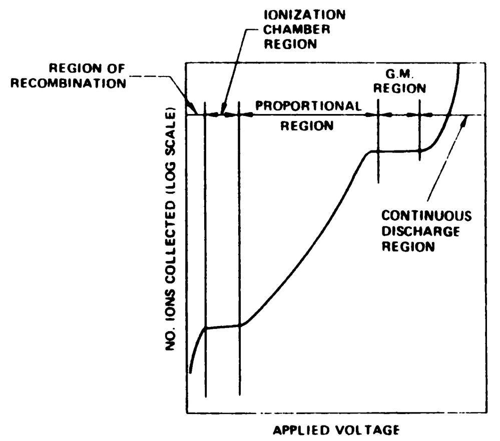
In today's laboratory, instruments will be used that have sensing elements which depend upon the collection of ions.




2. Composite Characteristic Curve for Ionization Detectors.

The composite curve for sensing elements that depend upon the collection of ions for their operation is shown in Figure 5 This hypothetical curve for gas ionization detectors is divided into five regions. The recombination region is where the ions produced by the radiation are under very low voltage gradients and tend to recombine with each other rather than migrate to the electrodes and be collected. The recombination of ion pairs decreases as the applied voltage is increased. The saturation or ionization chamber region begins at the voltage at which all ions formed are collected. As the voltage is increased within this region the ions are given more energy and move faster toward the collecting electrodes. However, they do not become energetic enough to produce additional ionization.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 5 |
|---|---|---|




2. Composite Characteristic Curve for Ionization Detectors (contd.)

The proportional region commences as the voltage is increased and the number of ions collected by the electrodes is greater than the number produced by the incident radiation. This effect is called gas amplification. The upper part of this region, is referred to as the region of limited proportionality. In the Geiger-Mueller region the increased voltage accelerates the primary electrons. The primary electrons interact with gas molecules, producing a sequence of ionizing events during their travel to the anode. A single ionizing event can produce a very large number of ions, consequently individual ionizing events may be detected. The continuous discharge region is reached above the Geiger-Mueller region. In this region the gas arcs, thereby producing a state of continuous discharge.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 6 |
|---|---|---|

**DETECTORS BASED ON COMPOSITE CURVE**

- IONIZATION CHAMBERS
  - EXPOSURE RATE
  - HIGH RADIATION LEVELS
- PROPORTIONAL INSTRUMENTS
  - DISCRIMINATION OF RADIATION TYPES
- G-M INSTRUMENTS
  - LOW RADIATION LEVELS

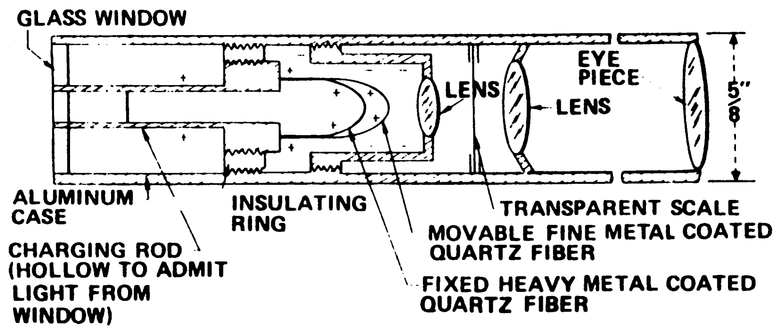
3. Detectors Based on Composite Characteristic Curve.

The ionization, gas proportional and Geiger-Mueller regions provide certain operating characteristics upon which radiation detectors have been designed. The ionization chamber is eminently suitable for indicating cumulative exposure or radiation exposure rate, since it provides a direct indication of the number of ions produced by a given radiation. Ion chambers are not sensitive to low radiation intensities. Complementary to their low sensitivity is their ability to measure large doses or high radiation intensities. Proportional instruments find their best use in the discrimination between alpha and beta radiation. They provide a pulse of current for every particle or photon which interacts within their chamber. G-M instruments are extremely sensitive indicating devices for measuring low intensities of radiation. They also provide a pulse of current for every particle or photon which interacts with the chamber.

Of the ion collecting sensors the Geiger counter and ionization chamber will be used in this laboratory exercise. The gas proportional counter will not be used.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 7 |
|---|---|---|

**POCKET DOSIMETER**




4. Laboratory Equipment

   a. Pocket Dosimeter

      A pocket dosimeter is a personally worn radiation detector whose sensing element depends upon the collection of ions produced by the incident radiation. It has the great advantages of compact size, readability and economy.

      The pocket dosimeter is about the size and shape of a large fountain pen. As depicted in Figure 7 the instrument contains an optical system and transparent scale. The chamber contains two electrodes, one of which is a quartz fiber loop free to move with respect to its mounting. Like charges are placed on the loop and its mounting by the charging device. Since like charges repel, the loop is forced outward from the mount. Radiation entering the chamber causes ionization within the sensitive volume. This ionization charge discharges the quartz fiber; the distance the fiber moves is proportional to the dose received in the chamber.

| L2 | CHARACTERISITCS OF IONIZATION CHAMBERS AND GEIGFR COUNTERS | 8 |
|---|---|---|

**POCKET DOSIMETER CHARACTERISTICS**

1. **RESPONDS TO X OR GAMMA RADIATION**
2. **RELATIVELY ENERGY INDEPENDENT ABOVE 200 KeV**
3. **DUST OR JARRING CAN DISCHARGE**
4. **INSULATOR MAY REQUIRE SOAK-IN**

4. Laboratory Equipment

a. Pocket Dosimeter (contd.)

Generally pocket dosimeters are designed to respond to X or gamma radiation, as the walls are too thick to admit beta radiation. They show some energy dependence in their sensitivity, and may therefore read erroneously. They are relatively energy independent above 200 KeV, but it is best to know what energy radiation is involved for correct interpretation.

A small amount of dust or lint on an insulator of one of these instruments can be enough to discharge it completely. Therefore, they must be kept clean. Dropping or sudden jarring will also sometimes discharge the instrument.

Insulator "soak-in" is a phenomenon regularly encountered in the operation of these chambers. When an instrument has been out of use for some time and is charged, a rather rapid discharge may be noted appearing as a high dose reading. This is due to the penetration of part of the charge into the insulator. To eliminate this problem, the instrument should be charged a day or more before it is used.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 9 |
|---|---|---|

**CHARGING AND READING DOSIMETER**

**CHARGING**

1. **INSERT DOSIMETER INTO CHARGER RECEPTACLE**
2. **ADJUST CHARGER CONTROL TO ZERO DOSIMETER**

**READING**

1. **POINT DOSIMETER TOWARD A LIGHT SOURCE**
2. **VIEW SCALE THROUGH EYEPIECE**

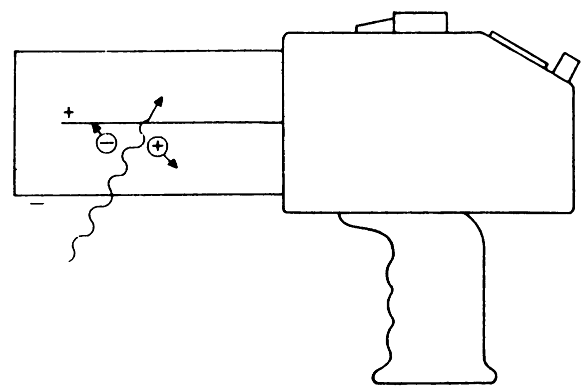
4. Laboratory Equipment

   a. Pocket Dosimeter (contd.)

   The dosimeter is charged by grasping its barrel firmly and inserting it into the receptacle provided on the charging device. A light in the charging device will illuminate the scale in the pocket dosimeter. While holding the pocket dosimeter in the socket and looking through the eyepiece adjust the control knob on the charging device until the pocket dosimeter scale reading has been zeroed. This is the manner by which the pocket dosimeter is charged. To make a reading of the dosimeter, hold it to a light source and view the scale through the eyepiece.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 10 |
|---|---|---|

**CUTIE PIE**



4. Laboratory Equipment (Contd.)

   b. Cutie Pie Ionization Chamber

      The Cutie Pie radiation chamber is another instrument in which the sensing element depends upon the collection of ions for its operation. The instrument operates in the ionization region of the composite curve of radiation detectors which was discussed earlier. The ionization initially produced within the chamber by radiation is measured without further gas-amplification.

      As depicted in Figure 10; radiation when passing through the chamber, collides with individual air molecules. The collision causes separation of an electron from the molecule creating an "ion pair". The electron from the "ion pair" is attracted to the collector electrode, which is positive with respect to the chamber walls. The balance of the original atom, which after separation of the electron retains a positive charge, is attracted to the negatively charged walls. Since the collector is well insulated, the electrons which land on its surface neutralize part of the initial positive charge. This negative shift in the collector is detected by an electrometer circuit. The graphite coated aluminum chamber is designed to approach as nearly as possible the performance of a hypothetical air wall chamber.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 11 |
|---|---|---|

**CUTIE PIE CHARACTERISTICS**

1. READING IS DIRECTLY RELATED TO THE TYPE, ENERGY AND QUANTITY OF INCIDENT RADIATION
2. CAN MEASURE HIGH RADIATION LEVELS
3. NOT A GOOD INSTRUMENT FOR LOW RADIATION LEVELS

4. Laboratory Equipment

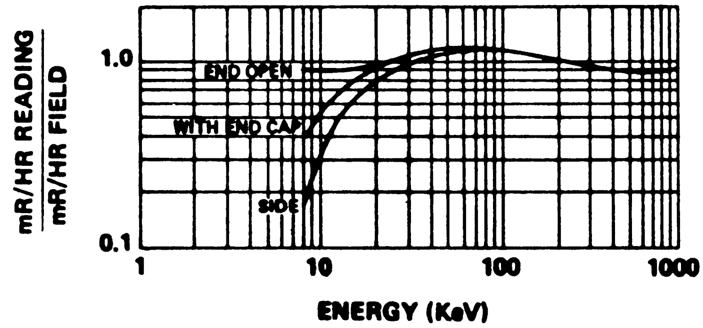
    b. Cutie Pie Ionization Chamber (contd.)

    The negative shift in the collector is directly related to the type, energy and quantity of radiation penetrating the chamber. With movable shields, it is possible to discriminate between types of radiation.

    In general, ionization chamber survey meters are used to measure relatively high level intensities. Their low sensitivity enhances their capacity to measure radiation at higher dosages or exposure rates. In x-ray survey work, calibrated ionization chamber instruments are used for measuring exposure rate.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 12 |
|---|---|---|

ENERGY DEPENDENCE
OF TYPICAL ION CHAMBER SURVEY METER




4. Laboratory Equipment

   b. Cutie Pie Ionization Chamber (contd.)

      As shown in Figure 12, ion chamber survey meters are energy independent in the MeV range, but occasionally exhibit relatively marked deviations at lower energies.

      The deviation is generally below 100 KeV. When using a given instrument its specifications should be checked to be certain of the energy dependence for the particular instrument.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 13 |
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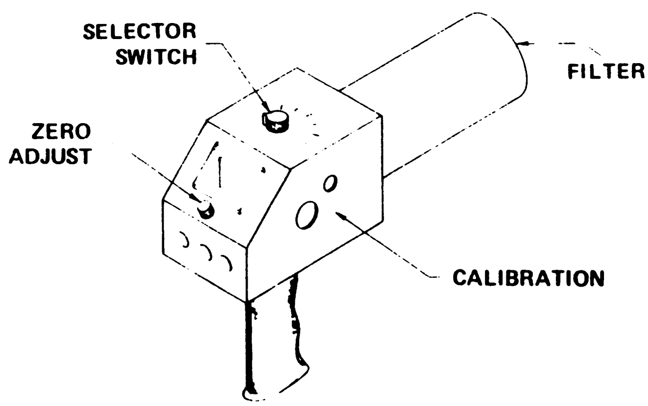
**TECHNICAL ASSOCIATES CP-5**




4. Laboratory Equipment

   b. Cutie Pie Ionization Chamber (contd.)

   A Technical Associates model CP5 Cutie Pie is shown in Figure 13. The main selector switch turns the instrument "OFF", permits battery interrogation, meter zeroing, and range selection. The zero adjust is used to zero the meter and is operative only when the main selector is in the "SET" position. The plugs covering the calibration controls can be removed to facilitate calibrating the instrument to a known radiation source. The calibration controls are not used during routine measurements and therefore have limited accessibility. The filters are designed to filter out alpha, beta radiation. The filter is attached so that it can be removed from the entrance port of the ionization chamber.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 14 |
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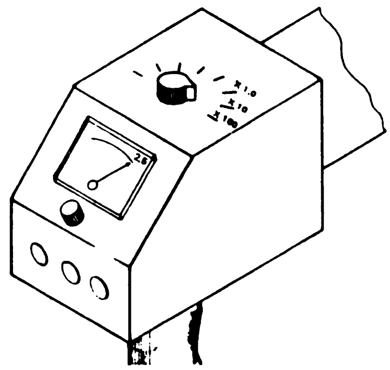
**READING THE SCALE**



2.5 mR/HR X 10 = 25 mR/HR

4. Laboratory Equipment

   b. Cutie Pie Ionization Chamber (contd.)

      The meter reading is given in mR/hr or R/hr. To obtain the final value the meter reading must be multiplied by the multiplier indexed by the main selector control. For example if the meter read 2.5 mR/hr and the selector was indexing the X10 range the final reading would be 2.5 x 10 mR/hr = 25 mR/hr.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 15 |
|---|---|---|

**BATTERY CHECK**

1. SELECTOR SWITCH IN SET POSITION
2. PRESS BATTERY CHECK SWITCH
3. METER NEEDLE IN GREEN INDICATES GOOD BATTERY

4. Laboratory Equipment

b. Cutie Pie Ionization Chamber (contd.)

The push button switch, located below the Zero adjust control on the Technical Associates' CP-5 is used to check battery condition. To test the battery the selector switch must be in the "SET" position. This position tests the battery at maximum load. The reading will be in the green area (upper 20% of scale) if the battery is good.

A manifestation of low battery is a gradual fluctuation of meter needle within a period in the order of a few seconds. Should such a fluctuation be noticed, replacement with a fresh battery is indicated.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 16 |
|---|---|---|

**METER ZEROING**

1. SELECTOR SWITCH TO SET
2. ADJUST ZERO ADJUSTER CONTROL TO ZERO METER
3. INTERNAL CONTROL MUST BE USED IF EXTERNAL ZERO ADJUST WILL NOT ZERO METER

4. Laboratory Equipment

b. Cutie Pie Ionization Chamber (contd.)

Having determined that the battery is in good condition, the instrument meter may now be zeroed using the following procedure.

Turn the selector switch to the SET position and adjust the ZERO ADJ. control until the meter reads exactly zero. If the batteries have not been checked prior to this time, it is recommended to wait 15 seconds before setting zero in order for the electrometer to warm up.

If the external Zero Control will not zero the meter, an internal Coarse Zero adjustment is available through a hole in the bottom of the case. This control should be adjusted in the following manner: Turn the Selector switch to the SET position. Turn the external Zero Control to approximately 3/4 of a revolution from the extreme counter-clockwise position. Adjust the internal Coarse Zero adjustment until the meter reads zero.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 17 |
|---|---|---|

**USING THE CP-5**

1. CHECK BATTERY
2. ZERO METER
3. TURN SELECTOR SWITCH TO OBTAIN MIDSCALE READING
4. POSITION FILTER
   GAMMA - FILTER ON
   ALPHA BETA GAMMA - FILTER OFF
5. CHECK ZERO DURING FIRST 30 MINUTES OF OPERATION

4. Laboratory Equipment

b. Cutie Pie Ionization Chamber (contd.)

Having checked the battery and zeroed the meter the instrument may be used in the following manner: Turn the Selector switch to the mR/hr X-1 position. If the meter reads off scale the radiation present is greater than 2.5 mR/hr and the switch should be turned to the appropriate higher scale.

To read gamma and alpha-beta sensitivities, move the plastic shield from in front of the window to the side of the chamber. Gamma readings are made with the filter in place.

The instrument should be returned to the SET position occasionally during the first 30 minutes of operation and the zero reset by turning the external zero control. After 30 minutes there should be no significant zero drift.

CAUTION

WITH FILTER BACK, THE ALPHA SCREEN IS EXPOSED AND CAN BE VERY EASILY DAMAGED. A VERY DELICATE TOUCH MAY CAUSE IT TO RIP.

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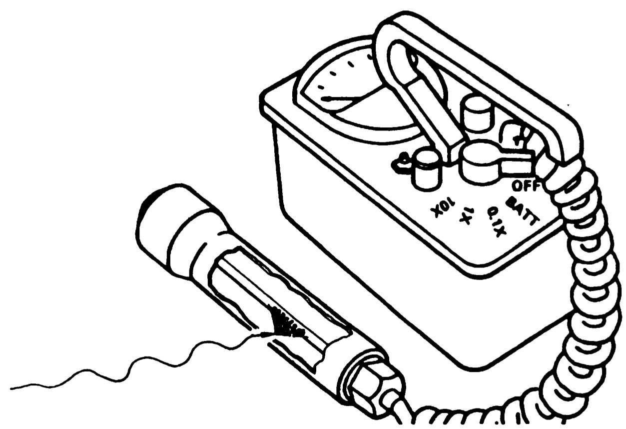
| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 18 |

**GEIGER COUNTER**




4. Laboratory Equipment (contd.)

c. Geiger Counter

Geiger counters use ion collecting sensing elements and may be used to detect low level, alpha, beta and gamma radiation. These instruments operate in the G-M region of the composite curve of radiation detectors which was discussed earlier. The ionization initially produced by the incident radiation, undergoes further gas amplification in the G-M tube. Thus a pulse of current is produced for every particle or photon which interacts in the tube. The resulting current is measured by a meter calibrated in counts per minute and mR/hr.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 19 |
|---|---|---|

**CHARACTERISTICS OF GEIGER COUNTER**

1. **NOT PRECISE AS AN EXPOSURE RATE METER**
2. **HIGH SENSITIVITY**
3. **CAN SATURATE IN HIGH RADIATION FIELDS**

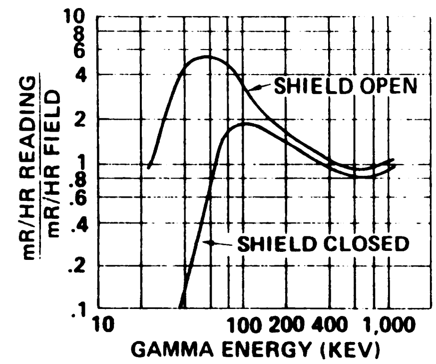
4. Laboratory Equipment

c. Geiger Counter (contd.)

It should always be remembered that the Geiger counter is not a precise instrument for exposure rate measurements, that is mR/hr. The response of this device is not directly proportional to the energy absorbed in the sensing element. The Geiger counter is best used as a device to detect the presence of radiation since it produces a pulse for every particle or photon which interacts within its chamber. In high radiation fields the Geiger counter can give false readings or become saturated and give an erroneously low reading.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 20 |
|---|---|---|

GEIGER COUNTER




4. Laboratory Equipment

   c. Geiger Counter (contd.)

      Geiger counter response is dependent upon the number of electrons that traverse its sensitive probe volume. And this number, in turn, is dependent on the energy of the photon and the range of the secondary electrons, provided the photoelectric emission is not pronounced.

      As shown in Figure 20, low energy photon radiation can result in considerable error. The decrease in the curve from .60 MeV downward is due to photoelectric absorption.

| | | |
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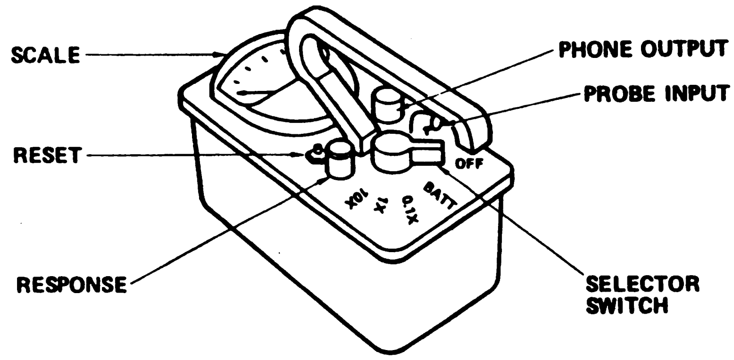
| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 21 |

**EXTERNAL CONTROLS OF THE EBERLINE E-120 PORTABLE SURVEY METER**




4. Laboratory Equipment

c. Geiger Counter (Contd.)

The Eberline Model E-120, shown in Figure 21, is a small, light-weight Geiger counter used for the detection and measurement of gamma, beta and alpha radiation with an external hand probe.

As shown, the five position selector switch turns the instrument OFF, checks the BATTery condition and selects scale multipliers of X0.1, X1 or X10. This number must be multiplied by the meater reading to obtain correct exposure or count rate. Response time of the meter is adjusted to the most desirable compromise between speed and fluctuation by using the response control. The reset button discharges the integrating capacitor, and brings the meter reading rapidly to zero. The scale is marked in Counts Per Minute (CPM) and milliroentgen per hour (mR/hr). The CPM scale is divided from 0-7K CPM with 35 increments and the mR/hr scale is divided from 0-5 with 25 increments. The phone output can be used to drive earphones, a speaker or an event counting device called a scaler. The probe input adaptor accepts the connector from the hand probe.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 22 |
|---|---|---|

**USING THE GEIGER COUNTER**

1. CHECK FOR PHYSICAL DAMAGE AND CONNECT PROBE TO INSTRUMENT
2. CHECK BATTERY BY TURNING SELECTOR SWITCH TO BATT POSITION
3. USE CHECK SOURCE
4. MOVE SELECTOR SWITCH TO OBTAIN AN UP SCALE READING
5. ADJUST RESPONSE CONTROL FOR DESIRED RESPONSE

4. Laboratory Equipment

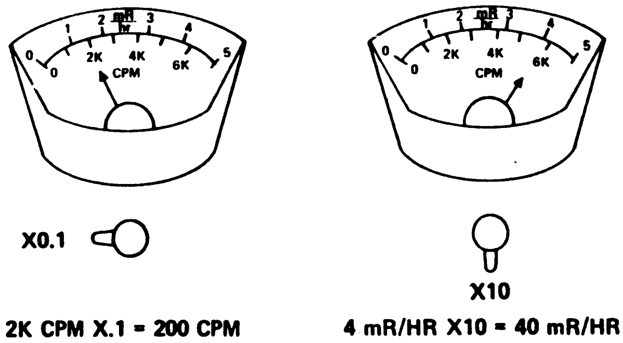
c. Geiger Counter (contd.)

Before making measurements the instrument should be checked for physical damage. Connect the probe cable to the angle probe connector on the instrument panel (if the probe cable has not previously been connected). To start the instrument turn the selector switch to the BATTery check position. The meter should indicate within the BATT OK area. Having determined that the battery is good and prior to any measurements, the instrument should be checked to insure that it is operating properly. An operation check is made by placing a check source, in this case a .005μ Ci $Tc^{99}$ beta emitter, in a repeatable position adjacent to the detector. Move selector switch to a range that gives an upscale reading. The instrument should give approximately the same check source reading each time the instrument is used. Care must be taken to insure that the source and detector are in the same repeatable positions each time the check is made. The reading of the check source should be recorded for future reference.

Pushing the Reset button while the check source is in position will cause the meter to drop to zero rapidly, then climb back to source reading when the reset is released. The Response may be adjusted to get the most desirable compromise between speed of response and meter fluctuation.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 23 |
|---|---|---|

**READING THE SCALES**




4. Laboratory Equipment

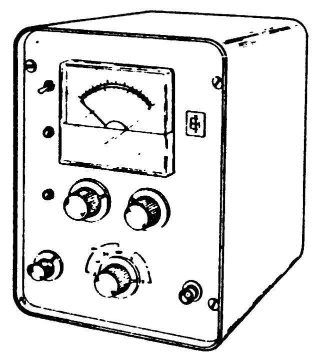
c. Geiger Counter (contd.)

The meter reading must be multiplied by the scale factor indexed by the rotary switch in order to obtain the proper number. For example, if the meter reading was 2 K CPM (K=1000) and the rotary switch was indexing the X.1 range, the correct count rate would be 2 K CPM multiplied by .1 or 200 counts per minute. If exposure rate was being measured instead of count rate and the meter read 4 mR/hr with a X10 multiplier the reading would be 4 mR/hr multiplied by 10 or 40 mR/hr. Fluctuation of the meter is normal and is caused by the random nature of radioactive decay.

The mR/hr and CPM scales of the Eberline E-120 are related such that a detected $Co^{60}$ count rate of 1400 CPM corresponds to an exposure rate of one mR/hr. This relationship holds only for $Co^{60}$. A radioactive source emitting radiation different in energy and type from that of $Co^{60}$ would correspond to a different exposure rate than one mR/hr. The geiger counter is better able to detect some types and energies of radiation better than others. Even assuming the geiger detection efficiency was the same for all types and energies of radiation 1400 CPM of alpha radiation would not correspond to the same number of mR/hr as 1400 CPM of gamma radiation.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 24 |
|---|---|---|

**EBERLINE MINI PULSER MODEL MP-1**



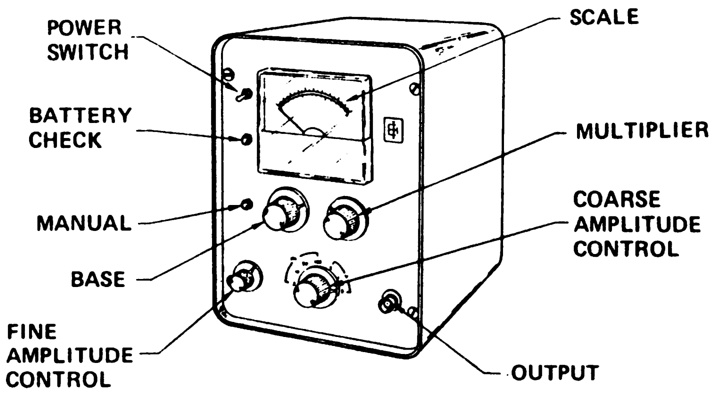
4. Laboratory Equipment (contd.)

   d. Mini Pulser

      The Model MP-1 Pulser, shown in Figure 24, is a small, lightweight pulse generator specifically designed to aid in calibrating a Geiger counter to CPM. The pulse repetition rate is variable from 10 CPM to 1.6 million CPM and is accurate to better than .1%. The pulse shape is tailored to simulate radiation detectors so the counting electronics will operate properly. The pulse amplitude is continuously variable from less than 1 millivolt to 3 volts and is displayed on the panel meter.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 25 |
|---|---|---|

**EBERLINE MINI PULSER MODEL MP-1**




4. Laboratory Equipment

   d. Mini Pulser (contd.)

      As shown in Figure 25, three controls determine output pulse repetition rate in counts (pulses) per minute. The base rotary switch establishes basic repetition rate. The multiplier rotary switch (mult) establishes the factor which is multiplied by the base number to determine output repetition rate. The manual push button is for manual control of the output repetition rate. (The base control must be in the manual position and the multiplier control has no effect.) One pulse is generated for each actuation of the manual push button.

      Two controls plus the meter readout are associated with the amplitude of the pulses. The coarse rotary switch establishes the amplitude range of the output. This control is marked in volts. The fine control determines amplitude over the range selected by the coarse switch. The amplitude of the pulse is read out on the meter scale. The battery check pushbutton control allows battery pack voltage to be presented to the meter. The power toggle switch turns the instrument on or off. Output is provided by a BNC series coaxial connector.

      The Geiger counter will be calibrated to CPM using the Mini pulser in the student's laboratory exercise.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 26 |
|---|---|---|

**STUDENTS' LABORATORY EXERCISE**

POCKET DOSIMTER
- EXPOSURE MEASUREMENT

CUTIE PIE
- CALIBRATION
- EXPOSURE RATE MEASUREMENT

GEIGER COUNTER
- CALIBRATION
- EXPOSURE RATE MEASUREMENT

## C. STUDENTS' LABORATORY EXERCISE

### 1. Introduction

During the laboratory exercise the students will have the opportunity to use the pocket dosimeter, the cutie pie, and the Geiger counter.

A dose calculation and a dose measurement will be made using the pocket dosimeter. Both the cutie pie and Geiger counter will be calibrated and used to measure the exposure rates from two radiation sources. These results will be compared.

| T (MINUTES) | mR/HR XT | DOSIMETER READINGS |
|---|---|---|
| 15 | | |
| 30 | | |
| 45 | | |
| 60 | | |
| mR/HR = 1,000 $I_\gamma C/d^2$ = d = 61 cm, C = 30 mCi | $I_\gamma$ = 13.1 mR cm$^2$/mCi hr FOR $Co^{60}$ | |

2. Use of a Pocket Dosimeter, Cutie Pie Ionization Detector and Geiger Counter.

   a. Pocket Dosimeter

      (1) Make a plot of exposure versus time at 2 feet for the 30 m Ci $Co^{60}$ calibration source. The exposure rate will need to be determined first. It can be calculated by the following formula,

      $$mR/hr = 1000\ I\gamma\ C/d^2$$

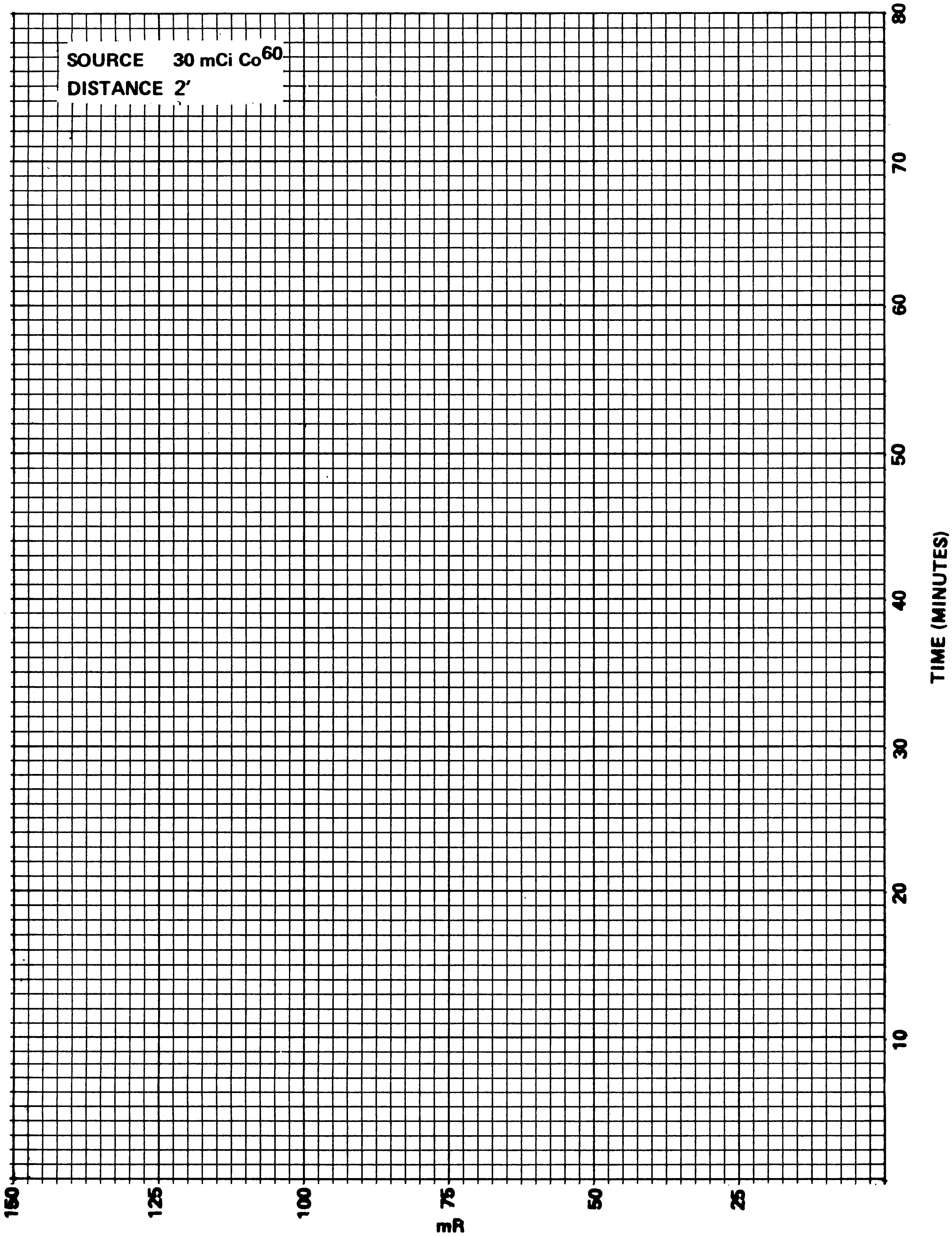
      $I\gamma$ is the specific gamma-ray emission, C is the number of millicuries of activity of the source, and d is the distance in cm. $I\gamma$ for $Co^{60}$ is 13.1 cm$^2$ mR/mc hr (3.4 for $Cs^{137}$). The exposure at d is simply the exposure rate times the time. Complete the table in Figure 27 and plot the values in Figure 28.

      (2) Charge and zero the pocket dosimeter.

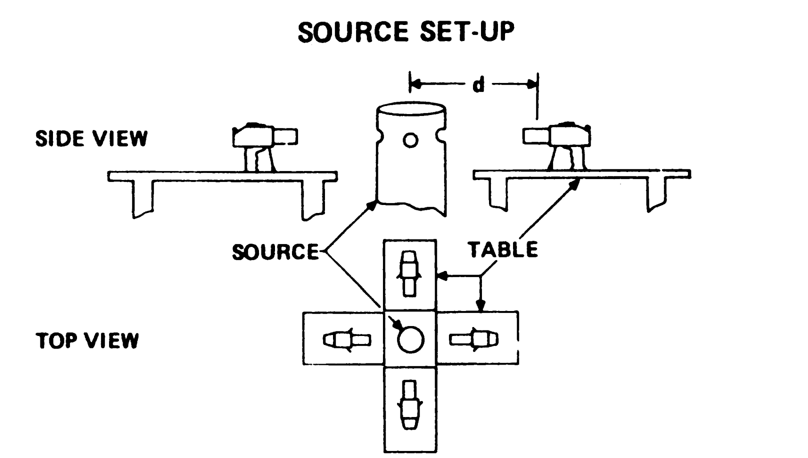
      (3) Place the dosimeter at 2 feet from the 30 m Ci $Co^{60}$ calibration source.

      (4) Make an exposure reading every 15 minutes. Use the timer for this purpose. Record values in Figure 27 and plot these observations in Figure 28. The 15 minute readings can be made as the cutie pie is calibrated in the following part of the experiment.

## EXPOSURE AS A FUNCTION OF TIME



| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 29 |
|---|---|---|




b. Cutie Pie Calibration

(1) Make a plot of exposure rate versus distance for the 30 m Ci $Co^{60}$ calibration source. Use Figures 30 and 31 for this purpose. Also make the same plot for the 60 m Ci $Cs^{137}$ source. Use Figures 30 and 31.

(2) The equipment will be set-up by the instructor as shown in Figure 29.

(3) Turn the C.P. ON and allow five minutes warm-up.

(4) Turn the selector switch to the SET position, check the battery and zero the meter using the zero control.

(5) Place the instrument in a radiation field of 20 mR/hr (30 m Ci $Co^{60}$) and turn the switch to the X-10 position on the mR/hr range. The distance from the source to the detector should be measured to the center of the ionization chamber and not to the window of the chamber.

(6) Remove the cover plug labeled MR Cal on the bottom of the case and adjust the internal control unit the meter reads 20 mR/hr.

(7) Place the instrument in the lowest radiation field possible (greatest practical distance) and check the meter reading. Accuracy of the calibration should be $\pm$ 10%.

(8) All mR/hr ranges are now calibrated. To assure tracking between ranges place instrument in radiation fields of 10, 25, 50, 100 and 200 mR/hr, with the range selector switch in the appropriate positions. The readings should check accurately. If they do not, readjust the mR/hr calibration setting to bring all readings within $\pm$ 10%.

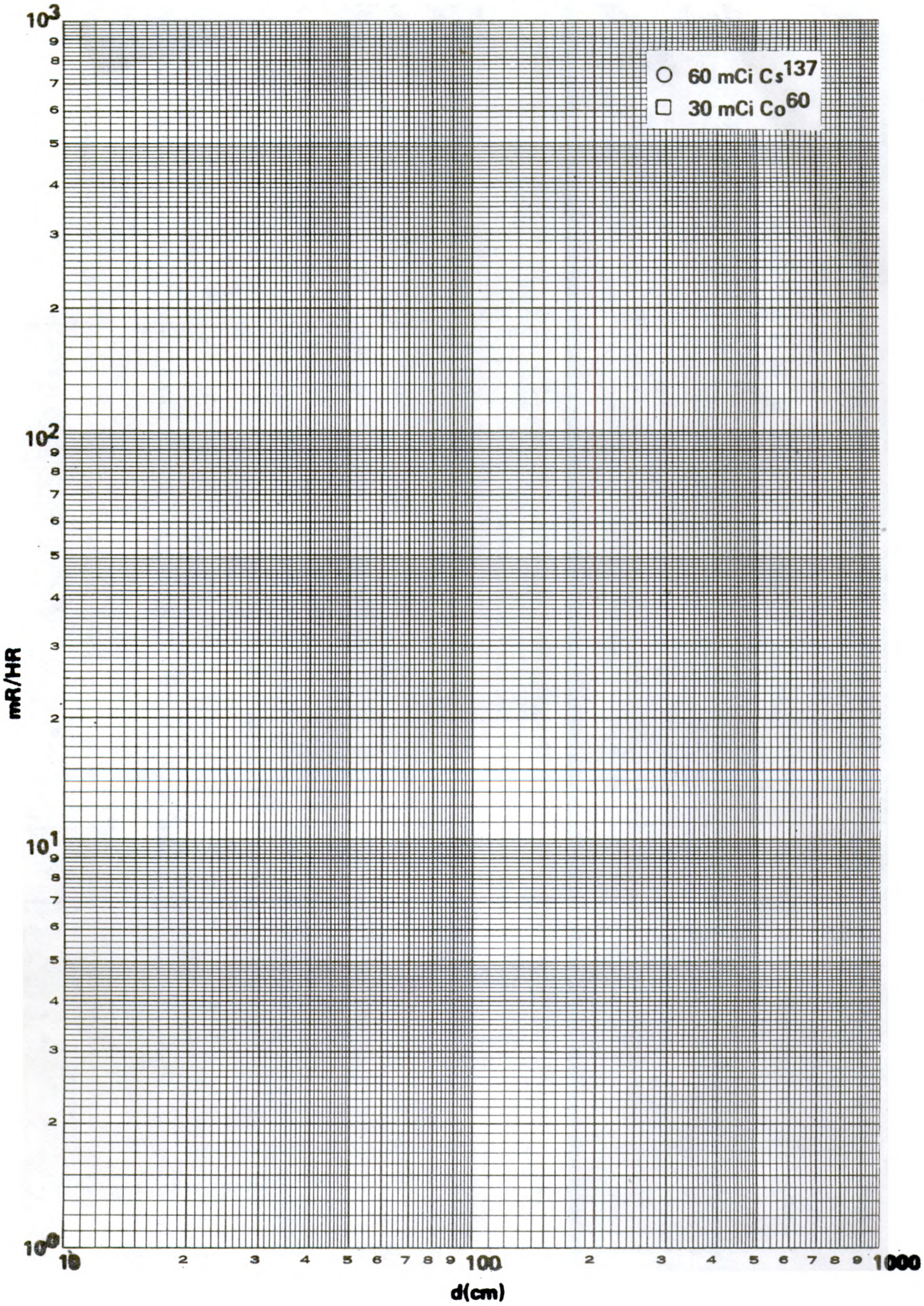
(9) It should be noted that some zero drift may occur during the first 30 minutes of operation. Therefore for accurate readings during this period occasional zero setting should be performed by turning the instrument to SET and adjusting the external control knob to re-establish the zero. Waiting 15 seconds before turning back to the radiation measuring ranges.

## CALCULATED EXPOSURE RATE

| $C = 30\text{m Ci } Co^{60}$ | $I_\gamma = 13.1\ cm^2 mR/mCi\ HR$ |
|---|---|
| d | $mR/HR = 1{,}000\ I_\gamma C/d^2$ |
| 1′ = 30.48 cm | |
| 2′ = 60.96 cm | |
| 4′ = 121.90 cm | |
| 6′ = 182.88 cm | |
| 8′ = 243.84 cm | |
| 10′ = 304.80 cm | |

| $C = 60\text{ mCi } Cs^{137}$ | $I_\gamma = 3.4\ cm^2 mR/mCi\ HR$ |
|---|---|
| d | $mR/HR = 1{,}000\ I_\gamma C/d^2$ |
| 1′ = 30.48cm | |
| 2′ = 60.96 cm | |
| 4′ = 121.90 cm | |
| 6′ = 182.88cm | |
| 8′ = 243.84cm | |
| 10′ = 304.80 cm | |

## EXPOSURE RATE VERSUS DISTANCE



| SOURCE | RANGE | DISTANCE | CALCULATED EXPOSURE RATE | MEASURED EXPOSURE RATE |
|---|---|---|---|---|
| 30 mCi $Co^{60}$ | X1 | | | |
| | | | | |
| | X10 | | | |
| | | | | |
| | X100 | | | |
| | | | | |
| 60 mCi $Cs^{137}$ | X1 | | | |
| | | | | |
| | X10 | | | |
| | | | | |
| | X100 | | | |
| | | | | |

c. Measuring Radiation Intensities Using the Cutie Pie

(1) The equipment will be set up by the instructor as shown in Figure 29. Turn on CP, check batteries, zero meter. Leave the filter in place.

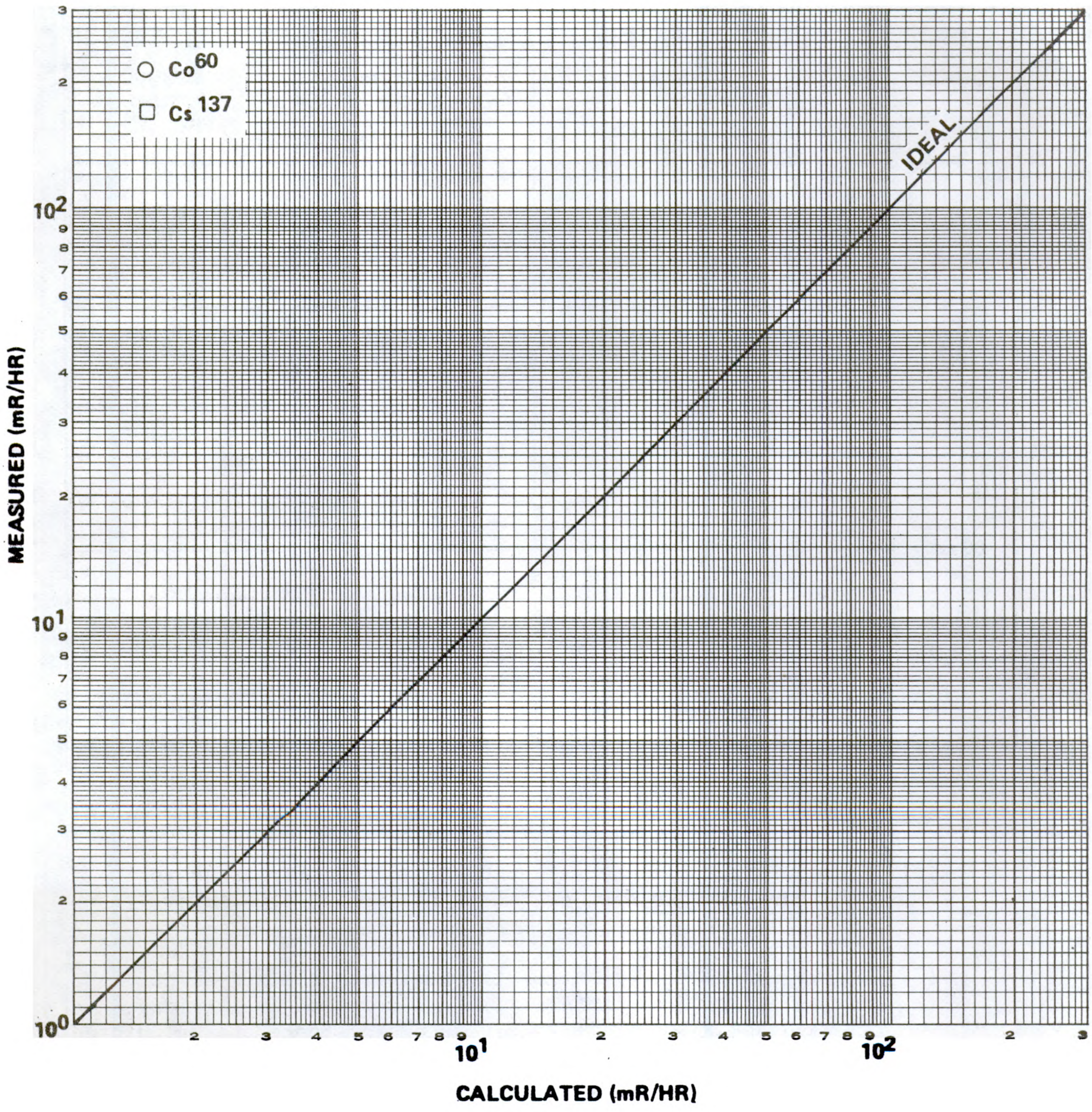
(2) Use Figure 31 to determine distances from the 30m Ci $Co^{60}$ source at which hi and low readings for each of the ranges X1, X10 and X100 can be made. Record distance and calculated exposure on Figure 32. Next place the CP at the two distances for each range, raise the source and record measured values in Figure 32.*

(3) Plot the values of Figure 32 on Figure 33. The measured values are plotted as a function of the calculated values (values obtained from graph). The ideal line is plotted so that the measured and calculated values are the same.

(4) Repeat steps 2 and 3 for the 60 m Ci $Cs^{137}$ source.

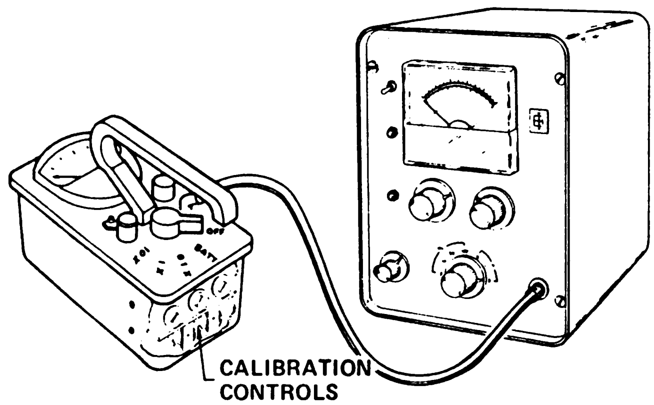
* The distance should be measured to the center of the ionization chamber and not to the window of the chamber.

CUTIE PIE



| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 34 |
|---|---|---|

**GEIGER COUNTER CALIBRATION**




d. Calibration of Geiger Counter to CPM Units.

(1) Couple the pulse generator to the probe input of the Geiger counter. Use a coaxial cable to connect the mini pulse output to the Geiger counter input, as shown in Figure 34.

(2) Set a frequency output of the mini pulser, (using the base and multiplier controls) which is conveniently read on the Geiger counter. Vary the coarse and fine amplitude controls until the point is found where the counter is marginally counting the input pulses. Adjust the amplitude slightly above this threshold. The pulse must be approximately 1/4 volts negative.

(3) Remove the Geiger counter from its protective housing so that its calibration controls are exposed (See Figure 34).

(4) With the range selector on the .1X range of the Geiger counter, adjust the pulse generator frequency (using the base and multiplier controls) to correspond with approximately 3/4 scale reading of the Geiger counter.

(5) Adjust the Geiger counter calibration control for the .1x range until the Geiger meter agrees with the frequency set on the pulse generator.

(6) Repeat steps 4 and 5 for the remaining ranges.

(7) Reassemble the Geiger counter.

| SOURCE | RANGE | DISTANCE | CALCULATED EXPOSURE RATE | MEASURED EXPOSURE RATE |
|---|---|---|---|---|
| 30 mCi | X1 | | | |
| | | | | |
| $Co^{60}$ | X10 | | | |
| | | | | |
| 60 mCi | X1 | | | |
| | | | | |
| $Cs^{137}$ | X10 | | | |
| | | | | |

e. Measuring Radiation Intensities Using the Geiger Counter.

(1) Set the equipment up as shown in Figure 29. Turn on the Geiger Counter and check the batteries and record the serial number of the G-M.

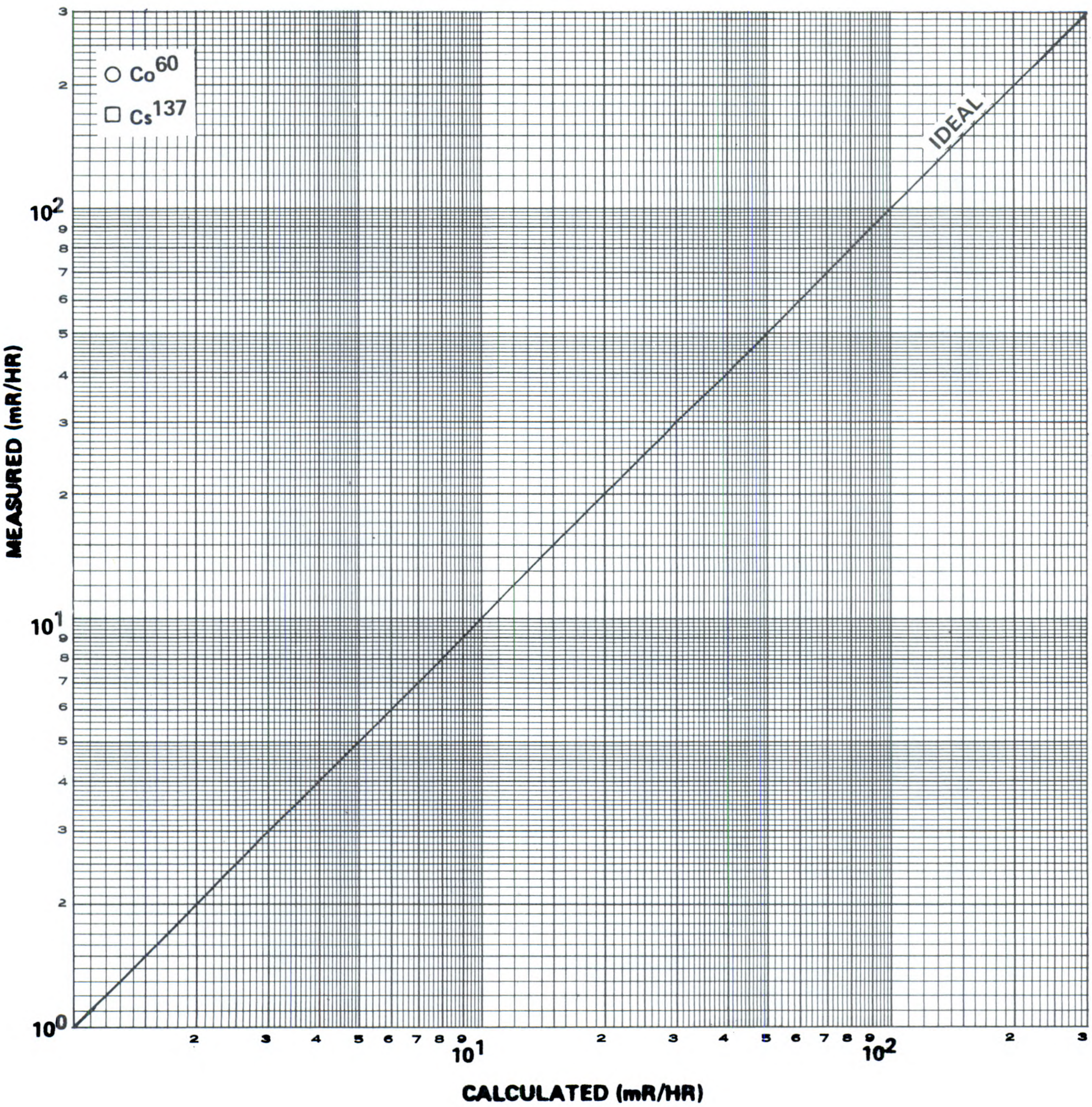
(2) Use Figure 31 to determine distances from the 30 m Ci $Co^{60}$ source at which hi and low scale readings for the ranges X1.0 and X10.0 can be made. Record these distances and exposures on Figure 35. Next place the Geiger Counter at the distances for each range, raise the source and record measured values on Figure 35. Source-to-instrument distances should be measured to the center of the probe held perpendicularly to the radiation field.

(3) Plot the values of Figure 35 on Figure 36. The measured values are plotted as a function of the calculated values (values obtained from graph). The ideal line is plotted so that the measured and calculated values are the same.

(4) Repeat steps 2 and 3 for the 60 m Ci $Cs^{137}$ source.

(5) Compare Figures 33 and 36. Which of the two types of survey instruments used is the most sensitive to low intensities of radiation? Which of these two kinds of radiation detectors more accurately measure mR/hr? Record your answer on Figure 36.

GEIGER COUNTER



# LABORATORY NO. 3
# RADIATION SURVEY

COURSE OUTLINE

III. RADIATION SURVEY

A. INTRODUCTION

1. Objectives
2. Overview
3. Equipment
4. Precautions

B. INSTRUCTOR'S DEMONSTRATION - LECTURE

1. Contamination

a. Definition
b. Airborne Contamination
c. Surface Contamination
d. Decontamination

2. Detection of Contamination

a. Special Detectors
b. Survey Meters
c. Smear Sampling
d. Leak Testing
e. Low Level Counting

3. Recording Results

a. Radiation Survey
b. Sealed Sources

4. Laboratory Equipment

a. Alpha Scintillation Detector
b. Scaler

C. STUDENTS' LABORATORY EXERCISE

1. Introduction

2. Phase I. Making a Radiation Survey

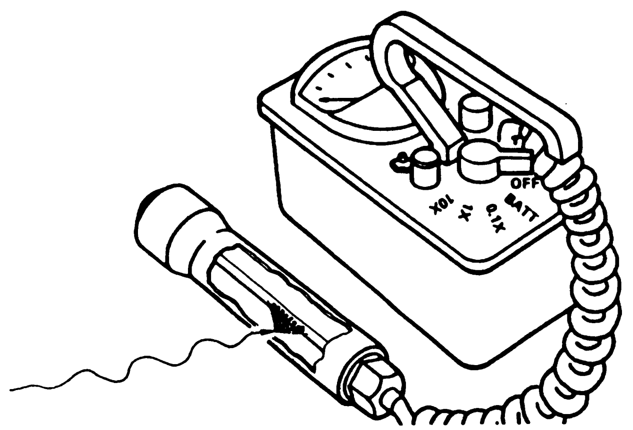
a. Alpha Source
b. Beta Source
c. Gamma Source

3. Phase II. Low Level Counting

a. Determination of Geiger Plateau
b. Counting of Alpha Smear
c. Counting of Beta Leak Test
d. Counting of Gamma Leak Test

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 18 |
|---|---|---|

**GEIGER COUNTER**




4. Laboratory Equipment (contd.)

   c. Geiger Counter

   Geiger counters use ion collecting sensing elements and may be used to detect low level, alpha, beta and gamma radiation. These instruments operate in the G-M region of the composite curve of radiation detectors which was discussed earlier. The ionization initially produced by the incident radiation, undergoes further gas amplification in the G-M tube. Thus a pulse of current is produced for every particle or photon which interacts in the tube. The resulting current is measured by a meter calibrated in counts per minute and mR/hr.

| I.2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 19 |
|---|---|---|

**CHARACTERISTICS OF GEIGER COUNTER**

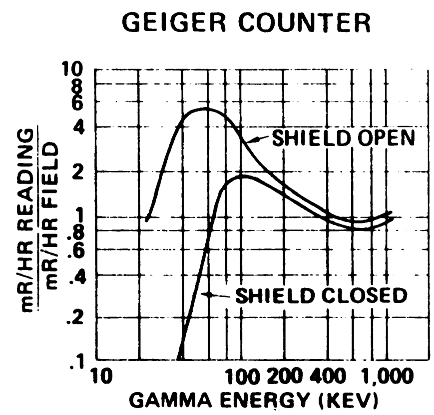
1. **NOT PRECISE AS AN EXPOSURE RATE METER**
2. **HIGH SENSITIVITY**
3. **CAN SATURATE IN HIGH RADIATION FIELDS**

4. Laboratory Equipment

   c. Geiger Counter (contd.)

      It should always be remembered that the Geiger counter is not a precise instrument for exposure rate measurements, that is mR/hr. The response of this device is not directly proportional to the energy absorbed in the sensing element. The Geiger counter is best used as a device to detect the presence of radiation since it produces a pulse for every particle or photon which interacts within its chamber. In high radiation fields the Geiger counter can give false readings or become saturated and give an erroneously low reading.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 20 |
|---|---|---|




4. Laboratory Equipment

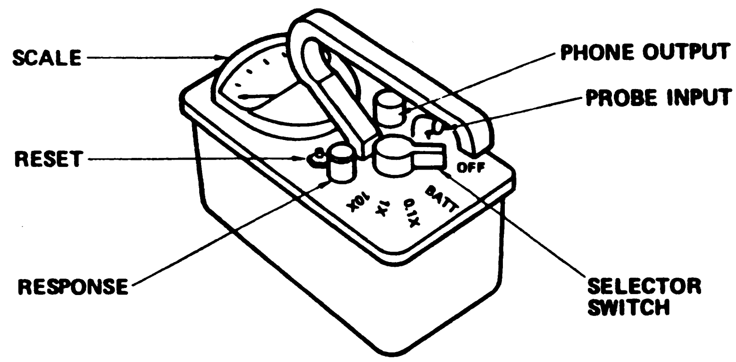
c. Geiger Counter (contd.)

Geiger counter response is dependent upon the number of electrons that traverse its sensitive probe volume. And this number, in turn, is dependent on the energy of the photon and the range of the secondary electrons, provided the photoelectric emission is not pronounced.

As shown in Figure 20, low energy photon radiation can result in considerable error. The decrease in the curve from .60 MeV downward is due to photoelectric absorption.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 21 |
|---|---|---|

**EXTERNAL CONTROLS OF THE EBERLINE E-120 PORTABLE SURVEY METER**




4. Laboratory Equipment

c. Geiger Counter (Contd.)

The Eberline Model E-120, shown in Figure 21, is a small, light-weight Geiger counter used for the detection and measurement of gamma, beta and alpha radiation with an external hand probe.

As shown, the five position selector switch turns the instrument OFF, checks the BATTery condition and selects scale multipliers of X0.1, X1 or X10. This number must be multiplied by the meater reading to obtain correct exposure or count rate. Response time of the meter is adjusted to the most desirable compromise between speed and fluctuation by using the response control. The reset button discharges the integrating capacitor, and brings the meter reading rapidly to zero. The scale is marked in Counts Per Minute (CPM) and milliroentgen per hour (mR/hr). The CPM scale is divided from 0-7K CPM with 35 increments and the mR/hr scale is divided from 0-5 with 25 increments. The phone output can be used to drive earphones, a speaker or an event counting device called a scaler. The probe input adaptor accepts the connector from the hand probe.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 22 |
|---|---|---|

**USING THE GEIGER COUNTER**

1. CHECK FOR PHYSICAL DAMAGE AND CONNECT PROBE TO INSTRUMENT
2. CHECK BATTERY BY TURNING SELECTOR SWITCH TO BATT POSITION
3. USE CHECK SOURCE
4. MOVE SELECTOR SWITCH TO OBTAIN AN UP SCALE READING
5. ADJUST RESPONSE CONTROL FOR DESIRED RESPONSE

4. Laboratory Equipment

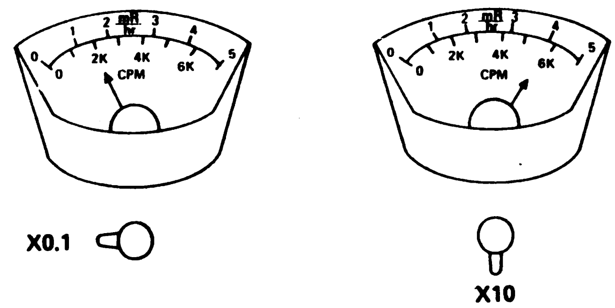
c. Geiger Counter (contd.)

Before making measurements the instrument should be checked for physical damage. Connect the probe cable to the angle probe connector on the instrument panel (if the probe cable has not previously been connected). To start the instrument turn the selector switch to the BATTery check position. The meter should indicate within the BATT OK area. Having determined that the battery is good and prior to any measurements, the instrument should be checked to insure that it is operating properly. An operation check is made by placing a check source, in this case a .005µ Ci $Tc^{99}$ beta emitter, in a repeatable position adjacent to the detector. Move selector switch to a range that gives an upscale reading. The instrument should give approximately the same check source reading each time the instrument is used. Care must be taken to insure that the source and detector are in the same repeatable positions each time the check is made. The reading of the check source should be recorded for future reference.

Pushing the Reset button while the check source is in position will cause the meter to drop to zero rapidly, then climb back to source reading when the reset is released. The Response may be adjusted to get the most desirable compromise between speed of response and meter fluctuation.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 23 |
|---|---|---|

**READING THE SCALES**




2K CPM X.1 = 200 CPM　　4 mR/HR X10 = 40 mR/HR

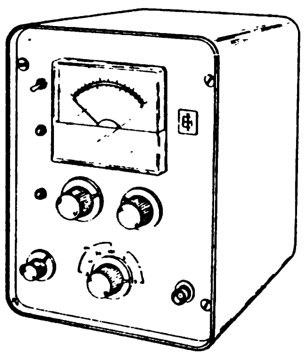
4. Laboratory Equipment

c. Geiger Counter (contd.)

The meter reading must be multiplied by the scale factor indexed by the rotary switch in order to obtain the proper number. For example, if the meter reading was 2 K CPM (K=1000) and the rotary switch was indexing the X.1 range, the correct count rate would be 2 K CPM multiplied by .1 or 200 counts per minute. If exposure rate was being measured instead of count rate and the meter read 4 mR/hr with a X10 multiplier the reading would be 4 mR/hr multiplied by 10 or 40 mR/hr. Fluctuation of the meter is normal and is caused by the random nature of radioactive decay.

The mR/hr and CPM scales of the Eberline E-120 are related such that a detected $Co^{60}$ count rate of 1400 CPM corresponds to an exposure rate of one mR/hr. This relationship holds only for $Co^{60}$. A radioactive source emitting radiation different in energy and type from that of $Co^{60}$ would correspond to a different exposure rate than one mR/hr. The geiger counter is better able to detect some types and energies of radiation better than others. Even assuming the geiger detection efficiency was the same for all types and energies of radiation 1400 CPM of alpha radiation would not correspond to the same number of mR/hr as 1400 CPM of gamma radiation.

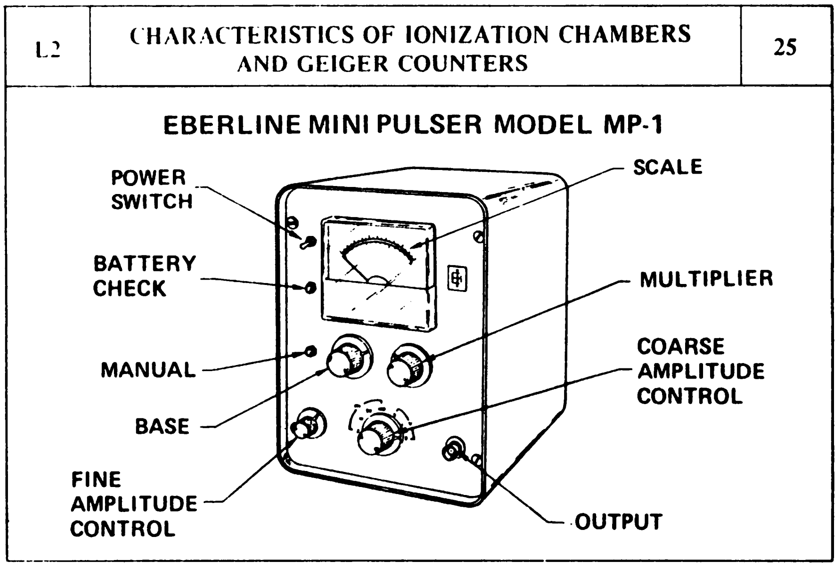
EBERLINE MINI PULSER MODEL MP-1



4. Laboratory Equipment (contd.)

d. Mini Pulser

The Model MP-1 Pulser, shown in Figure 24, is a small, lightweight pulse generator specifically designed to aid in calibrating a Geiger counter to CPM. The pulse repetition rate is variable from 10 CPM to 1.6 million CPM and is accurate to better than .1%. The pulse shape is tailored to simulate radiation detectors so the counting electronics will operate properly. The pulse amplitude is continuously variable from less than 1 millivolt to 3 volts and is displayed on the panel meter.




4. Laboratory Equipment

d. Mini Pulser (contd.)

As shown in Figure 25, three controls determine output pulse repetition rate in counts (pulses) per minute. The base rotary switch establishes basic repetition rate. The multiplier rotary switch (mult) establishes the factor which is multiplied by the base number to determine output repetition rate. The manual push button is for manual control of the output repetition rate. (The base control must be in the manual position and the multiplier control has no effect.) One pulse is generated for each actuation of the manual push button.

Two controls plus the meter readout are associated with the amplitude of the pulses. The coarse rotary switch establishes the amplitude range of the output. This control is marked in volts. The fine control determines amplitude over the range selected by the coarse switch. The amplitude of the pulse is read out on the meter scale. The battery check pushbutton control allows battery pack voltage to be presented to the meter. The power toggle switch turns the instrument on or off. Output is provided by a BNC series coaxial connector.

The Geiger counter will be calibrated to CPM using the Mini pulser in the student's laboratory exercise.

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 26 |
|---|---|---|

**STUDENTS' LABORATORY EXERCISE**

POCKET DOSIMTER
  EXPOSURE MEASUREMENT
CUTIE PIE
  CALIBRATION
  EXPOSURE RATE MEASUREMENT
GEIGER COUNTER
  CALIBRATION
  EXPOSURE RATE MEASUREMENT

## C. STUDENTS' LABORATORY EXERCISE

### 1. Introduction

During the laboratory exercise the students will have the opportunity to use the pocket dosimeter, the cutie pie, and the Geiger counter.

A dose calculation and a dose measurement will be made using the pocket dosimeter. Both the cutie pie and Geiger counter will be calibrated and used to measure the exposure rates from two radiation sources. These results will be compared.

| T (MINUTES) | mR/HR XT | DOSIMETER READINGS |
|---|---|---|
| 15 | | |
| 30 | | |
| 45 | | |
| 60 | | |
| mR/HR = 1,000 $I_\gamma C/d^2$ = | d = 61 cm<br>C = 30 mCi | $I_\gamma$ = 13.1 mR cm²/mCi hr FOR $Co^{60}$ |

2. Use of a Pocket Dosimeter, Cutie Pie Ionization Detector and Geiger Counter.

   a. Pocket Dosimeter

      (1) Make a plot of exposure versus time at 2 feet for the 30 m Ci $Co^{60}$ calibration source. The exposure rate will need to be determined first. It can be calculated by the following formula,

      $$mR/hr = 1000\ I\gamma\ C/d^2$$

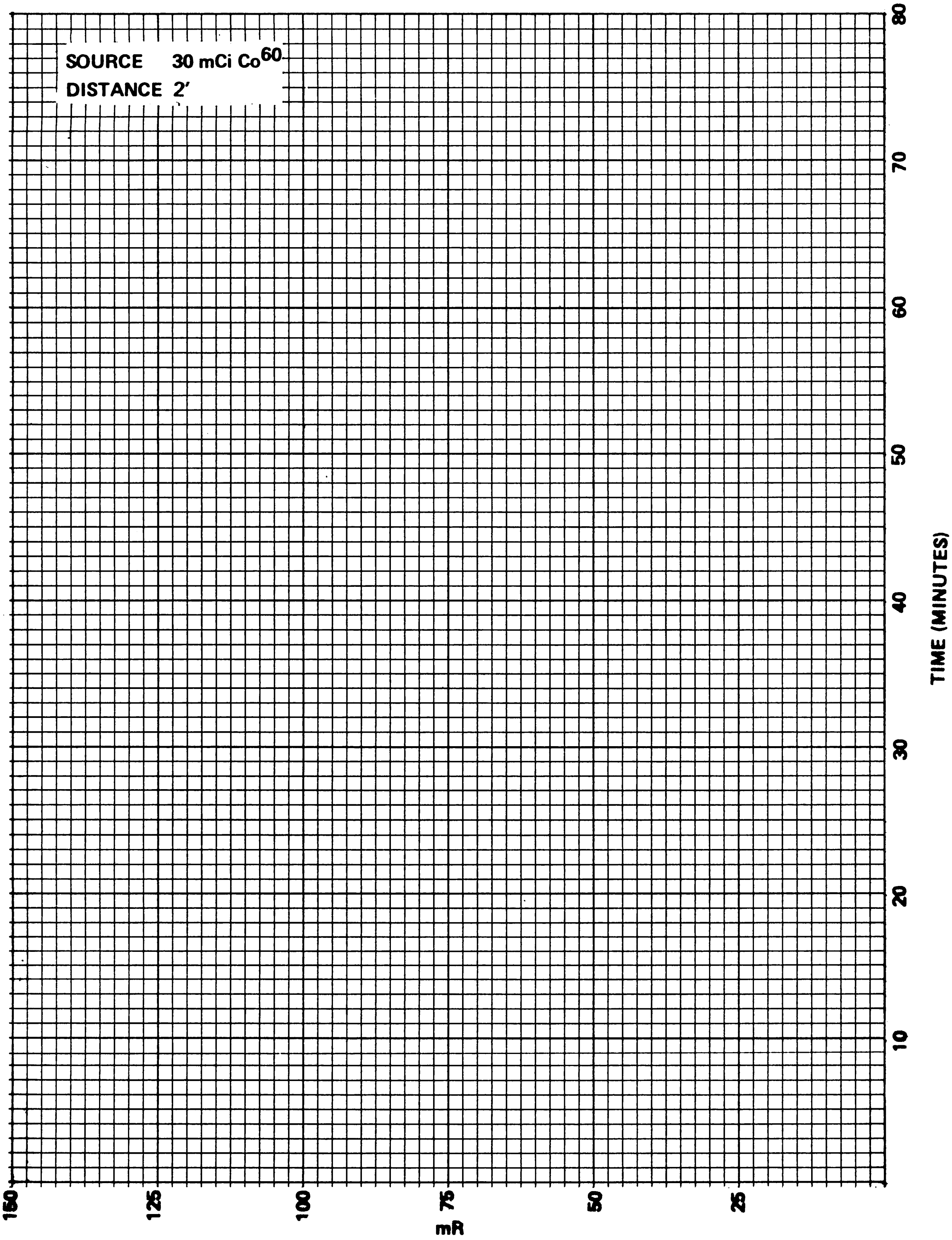
      $I\gamma$ is the specific gamma-ray emission, C is the number of millicuries of activity of the source, and d is the distance in cm. $I\gamma$ for $Co^{60}$ is 13.1 $cm^2$ mR/mc hr (3.4 for $Cs^{137}$). The exposure at d is simply the exposure rate times the time. Complete the table in Figure 27 and plot the values in Figure 28.

      (2) Charge and zero the pocket dosimeter.

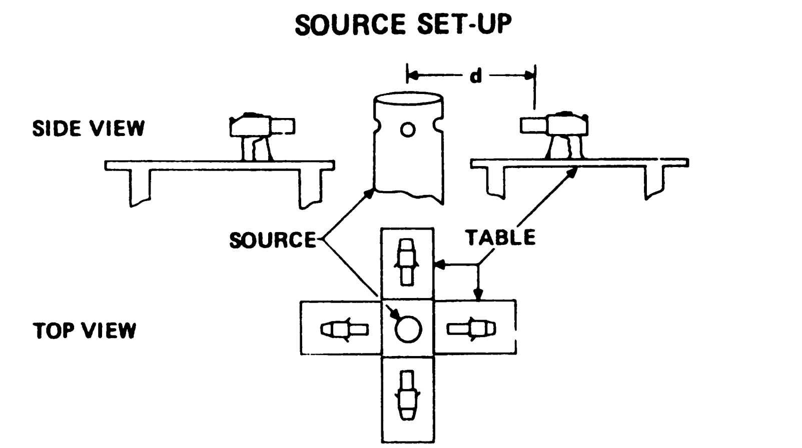
      (3) Place the dosimeter at 2 feet from the 30 m Ci $Co^{60}$ calibration source.

      (4) Make an exposure reading every 15 minutes. Use the timer for this purpose. Record values in Figure 27 and plot these observations in Figure 28. The 15 minute readings can be made as the cutie pie is calibrated in the following part of the experiment.

## EXPOSURE AS A FUNCTION OF TIME



| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 29 |
|---|---|---|




b. Cutie Pie Calibration

(1) Make a plot of exposure rate versus distance for the 30 m Ci $Co^{60}$ calibration source. Use Figures 30 and 31 for this purpose. Also make the same plot for the 60 m Ci $Cs^{137}$ source. Use Figures 30 and 31.

(2) The equipment will be set-up by the instructor as shown in Figure 29.

(3) Turn the C.P. ON and allow five minutes warm-up.

(4) Turn the selector switch to the SET position, check the battery and zero the meter using the zero control.

(5) Place the instrument in a radiation field of 20 mR/hr (30 m Ci $Co^{60}$) and turn the switch to the X-10 position on the mR/hr range. The distance from the source to the detector should be measured to the center of the ionization chamber and not to the window of the chamber.

(6) Remove the cover plug labeled MR Cal on the bottom of the case and adjust the internal control unit the meter reads 20 mR/hr.

(7) Place the instrument in the lowest radiation field possible (greatest practical distance) and check the meter reading. Accuracy of the calibration should be $\pm$ 10%.

(8) All mR/hr ranges are now calibrated. To assure tracking between ranges place instrument in radiation fields of 10, 25, 50, 100 and 200 mR/hr, with the range selector switch in the appropriate positions. The readings should check accurately. If they do not, readjust the mR/hr calibration setting to bring all readings within $\pm$ 10%.

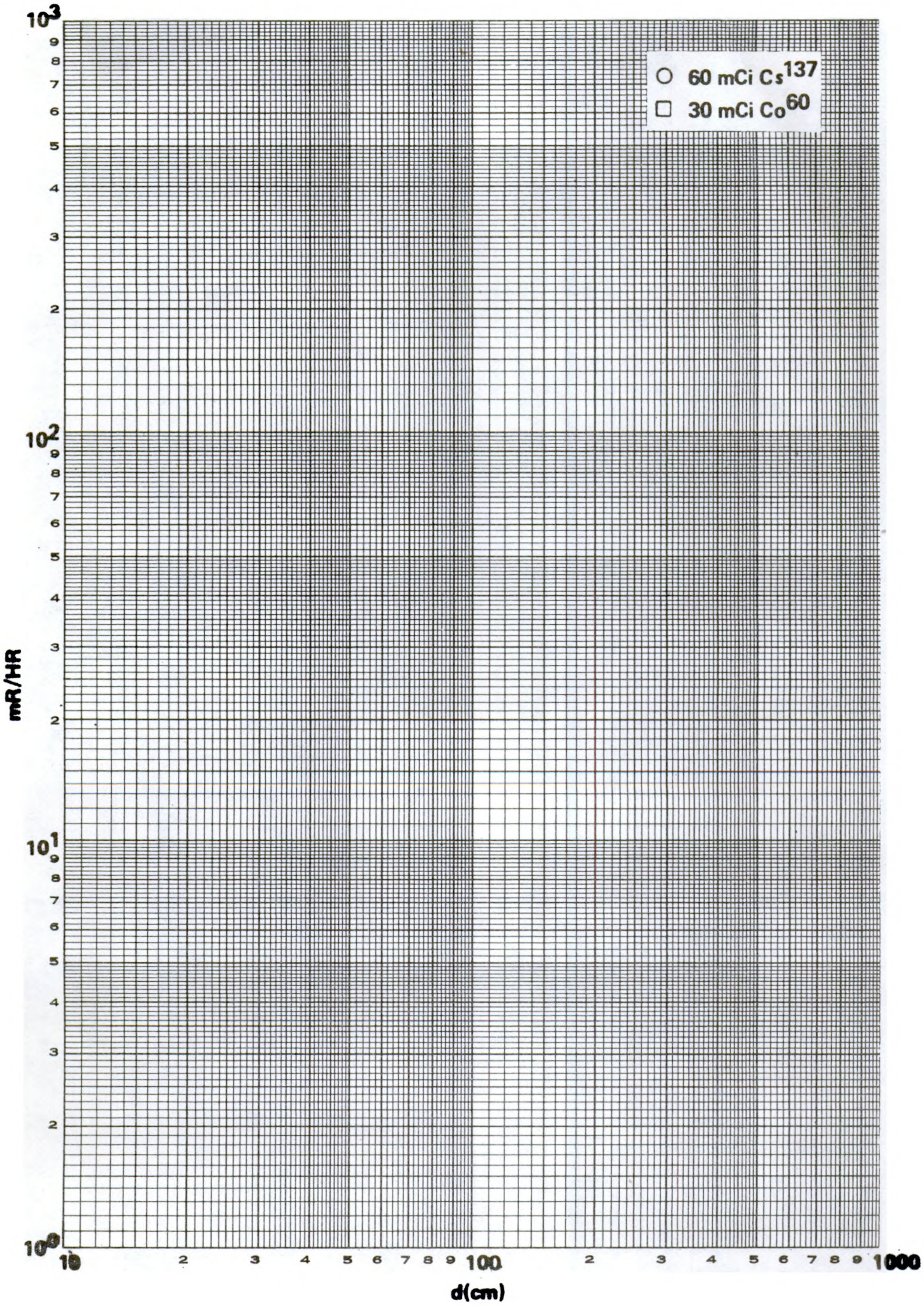
(9) It should be noted that some zero drift may occur during the first 30 minutes of operation. Therefore for accurate readings during this period occasional zero setting should be performed by turning the instrument to SET and adjusting the external control knob to re-establish the zero. Waiting 15 seconds before turning back to the radiation measuring ranges.

## CALCULATED EXPOSURE RATE

| C = 30m Ci $Co^{60}$ | $I_\gamma$ = 13.1 $cm^2$ m R/mCi HR |
|---|---|
| d | mR/HR = 1,000 $I_\gamma C/d^2$ |
| 1′ = 30.48 cm | |
| 2′ = 60.96 cm | |
| 4′ = 121.90 cm | |
| 6′ = 182.88 cm | |
| 8′ = 243.84 cm | |
| 10′ = 304.80 cm | |

| C = 60 mCi $Cs^{137}$ | $I_\gamma$ = 3.4 $cm^2$ m R/mCi HR |
|---|---|
| d | mR/HR = 1,000 $I_\gamma C/d^2$ |
| 1′ = 30.48 cm | |
| 2′ = 60.96 cm | |
| 4′ = 121.90 cm | |
| 6′ = 182.88 cm | |
| 8′ = 243.84 cm | |
| 10′ = 304.80 cm | |

## EXPOSURE RATE VERSUS DISTANCE



| SOURCE | RANGE | DISTANCE | CALCULATED EXPOSURE RATE | MEASURED EXPOSURE RATE |
|---|---|---|---|---|
| 30 mCi $Co^{60}$ | X1 | | | |
| | | | | |
| | X10 | | | |
| | | | | |
| | X100 | | | |
| | | | | |
| 60 mCi $Cs^{137}$ | X1 | | | |
| | | | | |
| | X10 | | | |
| | | | | |
| | X100 | | | |
| | | | | |

c. Measuring Radiation Intensities Using the Cutie Pie

(1) The equipment will be set up by the instructor as shown in Figure 29. Turn on CP, check batteries, zero meter. Leave the filter in place.

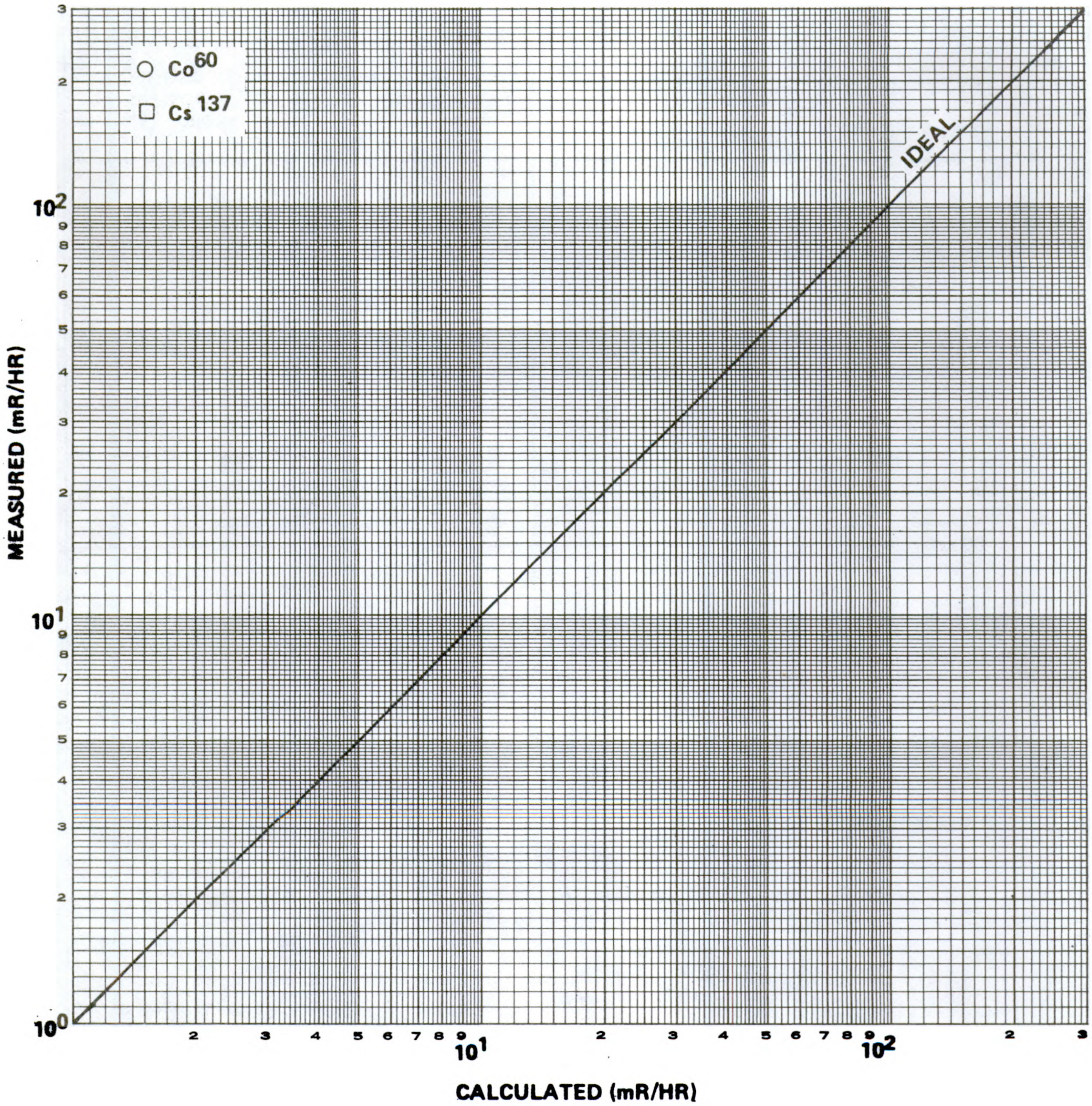
(2) Use Figure 31 to determine distances from the 30m Ci $Co^{60}$ source at which hi and low readings for each of the ranges X1, X10 and X100 can be made. Record distance and calculated exposure on Figure 32. Next place the CP at the two distances for each range, raise the source and record measured values in Figure 32.*

(3) Plot the values of Figure 32 on Figure 33. The measured values are plotted as a function of the calculated values (values obtained from graph). The ideal line is plotted so that the measured and calculated values are the same.

(4) Repeat steps 2 and 3 for the 60 m Ci $Cs^{137}$ source.

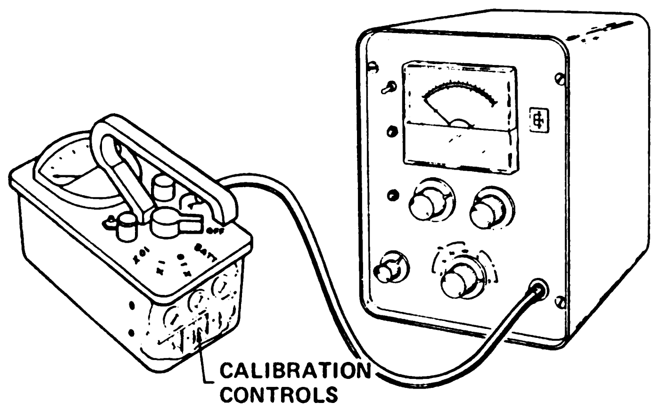
* The distance should be measured to the center of the ionization chamber and not to the window of the chamber.

CUTIE PIE


○ $Co^{60}$
□ Cs 137
IDEAL
MEASURED (mR/HR)
CALCULATED (mR/HR)
$10^0$
$10^1$
$10^2$
2
3
4
5
6
7
8
9

| L2 | CHARACTERISTICS OF IONIZATION CHAMBERS AND GEIGER COUNTERS | 34 |
|---|---|---|

**GEIGER COUNTER CALIBRATION**




d. Calibration of Geiger Counter to CPM Units.

(1) Couple the pulse generator to the probe input of the Geiger counter. Use a coaxial cable to connect the mini pulse output to the Geiger counter input, as shown in Figure 34.

(2) Set a frequency output of the mini pulser, (using the base and multiplier controls) which is conveniently read on the Geiger counter. Vary the coarse and fine amplitude controls until the point is found where the counter is marginally counting the input pulses. Adjust the amplitude slightly above this threshold. The pulse must be approximately 1/4 volts negative.

(3) Remove the Geiger counter from its protective housing so that its calibration controls are exposed (See Figure 34).

(4) With the range selector on the .1X range of the Geiger counter, adjust the pulse generator frequency (using the base and multiplier controls) to correspond with approximately 3/4 scale reading of the Geiger counter.

(5) Adjust the Geiger counter calibration control for the .1x range until the Geiger meter agrees with the frequency set on the pulse generator.

(6) Repeat steps 4 and 5 for the remaining ranges.

(7) Reassemble the Geiger counter.

| SOURCE | RANGE | DISTANCE | CALCULATED EXPOSURE RATE | MEASURED EXPOSURE RATE |
|---|---|---|---|---|
| 30 mCi | X1 | | | |
| | | | | |
| $Co^{60}$ | X10 | | | |
| | | | | |
| 60 mCi | X1 | | | |
| | | | | |
| $Cs^{137}$ | X10 | | | |
| | | | | |

e. Measuring Radiation Intensities Using the Geiger Counter.

(1) Set the equipment up as shown in Figure 29. Turn on the Geiger Counter and check the batteries and record the serial number of the G-M.

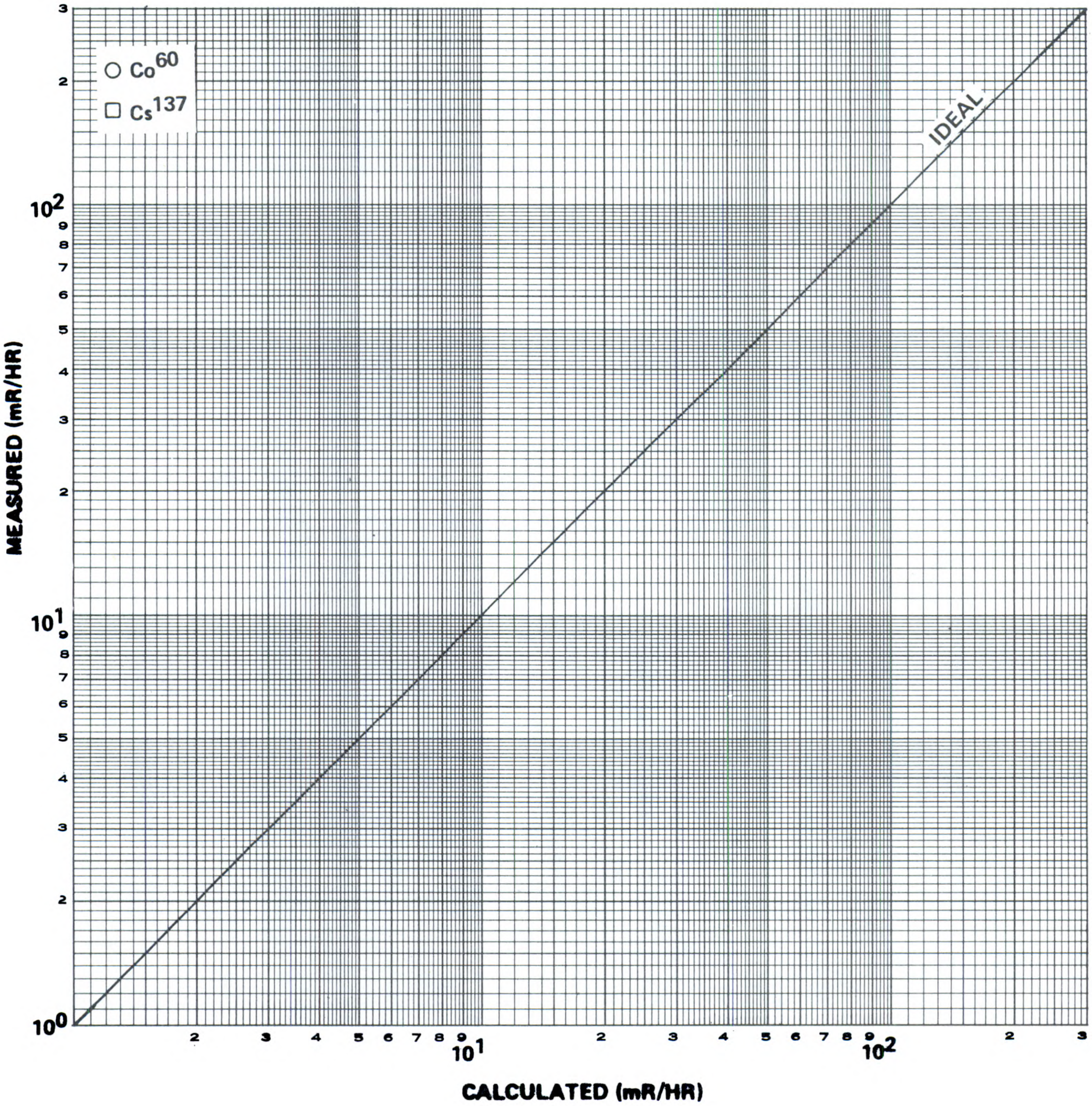
(2) Use Figure 31 to determine distances from the 30 m Ci $Co^{60}$ source at which hi and low scale readings for the ranges X1.0 and X10.0 can be made. Record these distances and exposures on Figure 35. Next place the Geiger Counter at the distances for each range, raise the source and record measured values on Figure 35. Source-to-instrument distances should be measured to the center of the probe held perpendicularly to the radiation field.

(3) Plot the values of Figure 35 on Figure 36. The measured values are plotted as a function of the calculated values (values obtained from graph). The ideal line is plotted so that the measured and calculated values are the same.

(4) Repeat steps 2 and 3 for the 60 m Ci $Cs^{137}$ source.

(5) Compare Figures 33 and 36. Which of the two types of survey instruments used is the most sensitive to low intensities of radiation? Which of these two kinds of radiation detectors more accurately measure mR/hr? Record your answer on Figure 36.

## GEIGER COUNTER



# LABORATORY NO. 3
# RADIATION SURVEY

COURSE OUTLINE

III. RADIATION SURVEY

A. INTRODUCTION

1. Objectives
2. Overview
3. Equipment
4. Precautions

B. INSTRUCTOR'S DEMONSTRATION - LECTURE

1. Contamination

   a. Definition
   b. Airborne Contamination
   c. Surface Contamination
   d. Decontamination

2. Detection of Contamination

   a. Special Detectors
   b. Survey Meters
   c. Smear Sampling
   d. Leak Testing
   e. Low Level Counting

3. Recording Results

   a. Radiation Survey
   b. Sealed Sources

4. Laboratory Equipment

   a. Alpha Scintillation Detector
   b. Scaler

C. STUDENTS' LABORATORY EXERCISE

1. Introduction

2. Phase I. Making a Radiation Survey

   a. Alpha Source
   b. Beta Source
   c. Gamma Source

3. Phase II. Low Level Counting

   a. Determination of Geiger Plateau
   b. Counting of Alpha Smear
   c. Counting of Beta Leak Test
   d. Counting of Gamma Leak Test

| L3 | RADIATION SURVEY | 1 |
|---|---|---|

**OBJECTIVES**

1. KNOW ABOUT DIFFERENT TYPES OF CONTAMINATION.
2. BE ABLE TO MAKE SMEAR AND LEAK TESTS.
3. BE ABLE TO USE AN ALPHA SCINTILLATION DETECTOR AND A SCALER
4. KNOW HOW TO REPORT RESULTS OF A RADIATION SURVEY

# III. RADIATION SURVEY

## A. INTRODUCTION

### 1. Objectives

a. Know about different types of contamination

b. Be able to make smear and leak tests

c. Be able to use an alpha scintillation detector and a scaler

d. Know how to report results of a radiation survey

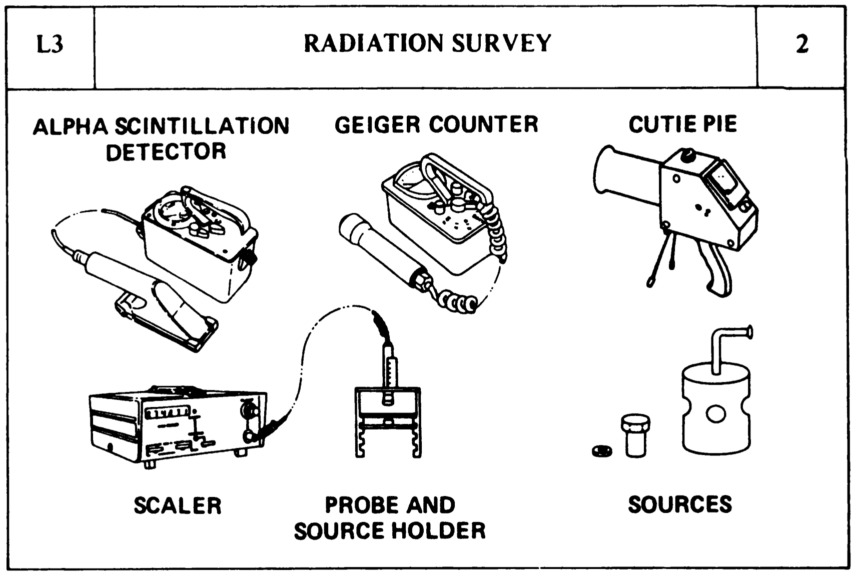
### 2. Overview

The instructor will begin the laboratory by stating the objectives, identifying major pieces of laboratory equipment and pointing out precautions to be followed.

The instructor's demonstration-lecture will start with a brief discussion of contamination and decontamination. Instruments used for detecting contamination will be pointed out and the procedure used in making leak tests and smear tests will be discussed and demonstrated. The procedure followed in counting smears using a scaler set-up will also be presented. Forms for reporting results of contamination checks will be explained.

The students will use an alpha scintillation detector, a cutie pie, and a Geiger counter to make direct readings of several radiation sources. Some of these sources will be checked for leaks. The leak tests, as well as a smear test will be counted using a scaler set-up. The results of the smear and leak tests will be reported on appropriate forms.

The laboratory exercise will be submitted to the instructor at the completion of the lab session.




3. Equipment

a. Alpha Scintillation Detector Eberline PAC-ISAGA with AC-3 Probe

b. Geiger Counter-Eberline E-120 with HP-190 Probe

c. Cutie Pie-Technical Associates CP-5

d. Scaler-Eberline MS-3

e. Probe and Source Holder

f. Nu-Con Smears, Q-tips

g. Pocket Dosimeter, Pocket Dosimeter Charger, Film Badge, Finger Ring

h. Lab Coats, Rubber Gloves, Radioactive Waste Container, Lead Bricks

i. Radioactive Sources

| | |
|---|---|
| .005$\mu$Ci $Tc^{99}$ | Check Source |
| .001$\mu$Ci $Am^{241}$ | Check Source |
| .1$\mu$Ci $Am^{241}$ | Direct Alpha and Calibration Source |
| .1$\mu$Ci $Sr^{90}$ | Direct Beta, Leak Test and Calibration Source |
| 30m Ci $Co^{60}$ | Direct Gamma & Leak Test |
| .3$\mu$Ci $Co^{60}$ | Calibration Source |

| L3 | RADIATION SURVEY | 3 |
|---|---|---|

**PRECAUTIONS**

1. DO NOT DIRECTLY TOUCH A RADIO-ACTIVE SOURCE
2. AVOID UNNECESSARY EXPOSURE
3. WEAR A FILM BADGE, FILM RING AND A POCKET DOSIMETER AT ALL TIMES

4. Precautions

These precautions will be followed during the demonstration and during the students' laboratory exercise.

| L3 | RADIATION SURVEY | 4 |
| --- | --- | --- |
| | RADIOACTIVE CONTAMINATION<br><br>1. PRESENCE OF UNDESIRED RADIO-ACTIVE MATERIALS<br><br>2. CAN BE FOUND IN THE AIR OR ON SURFACES | |

## B. INSTRUCTOR'S DEMONSTRATION-LECTURE

1. Contamination

   a. Definition

      Radioactive contamination may be defined as the undesired presence of radioactive materials in amounts that may be harmful to the health and safety of personnel, and to the validity of experiments or products. The contamination can be found in the air or may be deposited on surfaces.

      The detection and removal of the contamination involves different methods depending upon whether it is in the air or on surface.

| L3 | RADIATION SURVEY | 5 |
|---|---|---|

**AIRBORNE CONTAMINATION**

1. **NECESSITATES AIR MONITORING**
2. **CONSISTS OF MICROSCOPIC SOLID PARTICLES OR DUST**

1. Contamination (contd.)

    b. Airborne Contamination

    When an airborne radiation potential exists, it becomes necessary to monitor the air. Air monitoring consists of collecting and analyzing air samples to detect airborne contamination. Most airborne contamination is in the form of microscopic solid particles or dust. Air samples representative of the hazard to personnel are taken at the breathing zone near where the individual is working. After a sample of gas, vapor, or particulate is obtained, it must be counted. Special instruments have been developed to handle the various types of specimens.

| L3 | RADIATION SURVEY | 6 |
|---|---|---|

**SURFACE CONTAMINATION**

1. **LOOSE – READILY REMOVABLE**
2. **FIXED – NOT READILY REMOVABLE**

1. Contamination (contd.)

c. Surface Contamination

Surface contamination may be loose or fixed. Loose contamination is contamination that is easily and readily removable from the surfaces of structures, areas, objects or personnel. Fixed contamination is contamination that is not readily removable. Today's laboratory is concerned with techniques of detection of surface contamination.

| L3 | RADIATION SURVEY | 7 |
|---|---|---|

**DECONTAMINATION**

1. **REDUCTION OR REMOVAL OF CONTAMINATING RADIOACTIVE MATERIAL**
2. **CAN BE REDUCED BY:**

   **NATURAL DECAY**
   **COVER WITH ABSORBER**
   **SURFACE TREATMENT**
   **FILTERING**

1. Contamination (contd.)

   d. Decontamination

   Decontamination is the reduction or removal of contaminating radioactive material from a structure, area, object, or person.

   Decontamination may be accomplished by several methods. If the radioactivity has a short half-life the material can be let alone so that the activity is decreased as a result of natural decay. The contamination can be covered to attenuate the radiation emitted. The surface can be treated to remove or decrease the contamination. Contamination in the air can be removed by the use of filters.

   Since radioactivity is a property of the nucleus and not of the election shells, its destruction or neutralization cannot be accomplished by chemical action. Certain chemicals are, however, very useful in removing the contaminants from surfaces and media to allow safe utilization of these areas or items after decontamination.

| L3 | RADIATION SURVEY | 8 |
|---|---|---|

## SPECIAL DETECTORS

1. HAND AND FOOT COUNTERS
2. FRISKERS
3. LAUNDRY MONITORS
4. AIR SAMPLERS

2. Detection of Contamination

   a. Special Detectors

   Certain contamination problems may necessitate the use of hand and foot counters. These counters are AC powered multiple GM tube type instruments specifically designed for checking the hands and feet for beta-gamma contamination.

   Portal monitors or "Friskers" may be installed around door openings to check on clothing contamination of individuals passing through.

   GM tube laundry monitors are used to check clothing contamination both before and after laundering.

   Air sampling techniques are also important in monitoring for contamination.

   Portable pump samplers utilize a filter through which is pumped a constant flow of air. The filter can be removed after a predetermined sampling period and counted in conventional counters.

   Fixed filter GM tube type air samplers are available which continuously sample and record activity in a given zone. Their tubes must be shielded to provide low background.

| L3 | RADIATION SURVEY | 9 |
|---|---|---|

## SURVEY METERS

1. ALPHA
   - PROPORTIONAL ALPHA COUNTERS
   - SAMPSON
   - JUNO
   - ALPHA SCINTILLATION
2. BETA-GAMMA
   - CUTIE PIE
   - JUNO
   - GM
   - SCINTILLATION

2. Detection of Contamination (contd.)

b. Survey Meters

Some type of portable survey meter is usually used to determine the magnitude of fixed surface contamination.

Alpha survey meters include the proportional alpha counter, Sampson, Juno, and alpha scintillation counters.

The proportional alpha counter and most scintillation instruments can be biased and made insensitive to beta-gamma radiations.

The Cutie Pie, Juno, GM Survey Meter, and special scintillation survey meters are used to detect and measure beta and beta-gamma activity.

The GM Survey Meter is the best detection device for beta-gamma activity. It is widely used as a beta detector since it has a rather high (~90%) efficiency for beta particles.

The Juno and certain scintillation survey meters may also be used as beta and beta-gamma detectors; however, it is usually difficult to detect low levels of surface contamination with the Juno type.

| L3 | RADIATION SURVEY | 10 |
|---|---|---|

**SMEAR SAMPLING**

1. **UNIFORM WIPING OF A 100 SQ. CM. AREA**
2. **COUNTED WITH A SCALER**

2. Detection of Contamination (contd.)

   c. Smear Sampling

   Smears are important methods by which loose surface contamination is investigated. A smear is produced by wiping an area of 100 square centimeters (an area 3.96" x 3.96") with an absorbent disc (e.g., Nu-Con Smears). Care is taken to apply uniform pressure while wiping with the absorbent disc. This, in theory, insures consistent pickup of the contamination. The smear may be made wet by using an alcohol solvent. Smears are counted with a laboratory instrument and the results are reported in disintegrations per minute per 100 $cm^2$. The scaler counting efficiency must be accounted for since the approximate absolute activity is reported. Used smears are placed in radioactive waste containers.

   The smear technique can be used most effectively as a check on contamination control measures and as a method for determining the thoroughness of decontamination efforts.

   Smearing is a qualitative method although considerable emphasis is placed on quantitative results.

RADIATION SURVEY 11

L3

## LEAK TESTING

**SAMPLING OF A SEALED RADIOACTIVE CONTAINER**

**LEAKS DUE TO:**
- **VESSEL PRESSURE**
- **CORROSION**
- **MECHANICAL DAMAGE**

**REGULARITY OF LEAK TESTING IMPORTANT**

Contamination (contd.)

### ›ak Testing

A sealed source is a radioactive source sealed in an impervious container which has sufficient mechanical strength to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed. Even though sealed sources are designed not to leak, it is still necessary to periodically check their integrity.

Sealed sources may develop leaks due to several causes. The internal vessel pressure may increase as a result of alpha decay. If the helium pressure due to alpha decay becomes sufficiently great, it may cause the container to leak. Water vapor pressure also may build-up. The container can be attacked by chemicals and corrosive fumes. Physical damage may occur from vibration, shock, or undue mechanical stress. The capsule material may deteriorate permitting contamination to spread from the confined area.

Because sealed sources may develop leaks, they should be tested regularly. Wiping the container with a Q-tip is a common method of leak testing sealed sources. The Q-tip is placed in a plastic container for transportation and is subsequently counted.

Regardless of what method is incorporated, regularity with any given technique is most important. Sealed sources should be checked at least every 6 months and a continuing record should be kept.

L3 | RADIATION SURVEY | 12

## SCALER

1. USED TO DETERMINE THE ACTIVITY OF RADIOACTIVE SAMPLES
2. COUNTS NUMBER OF PULSES FROM GM TUBE FOR A GIVEN TIME
3. ADDS PULSES ELECTRONICALLY

2. Detection of Contamination (contd.)

e. Low Level Counting

A scaler can be used to determine the activity of radioactive samples.

A scaler counts the total number of pulses from a GM tube in any given amou time. The scaler, can thus be considered to be an electronic "adding machine" w accepts the pulses from the GM tube and accumulates them. The instrument a electronically, because pulses are received at too rapid a rate to be added by mechanical device. Because a scaler counts all of the pulses from the GM tube anc presents the total in any given amount of time, it is a rather accurate instrument for the determination of a radioactive count rate. Count rate is obtained by dividing the count by the counting time interval.

**NET EFFICIENCY**

**NUMBER OF IONIZING EVENTS COUNTED DIVIDED BY NUMBER OF PARTICLES ACTUALLY EMITTED**

factors. Since a
arrange a detection
The detector usually
on. Thus, the counting
This factor depends on
the detector is to the
counted.

, not every radiation that
exhibits different counting

stem is an indication of the number of ionizing
he number of particles actually emitted. For
eing emitted each minute and the instrument
e net efficiency would be 50 percent.

L3 | RADIATION SURVEY | 14

**FACTORS AFFECTING NET EFFICIENCY**

1. GEOMETRICAL EFFICIENCY
2. COUNTING EFFICIENCY
3. SCATTERING
4. ABSORPTION
5. RESOLVING TIME
6. BACKGROUND

2. Detection of Contamination

e. Low Level Counting (contd.)

The net efficiency of a detecting system depends upon man radioactive source emits radiation in all directions, it is difficult t system that intercepts all the radiation that is being emitted. intercepts only a small fraction of the spherically emitted radiati system is limited by what can be called geometrical efficiency. the relative positions of the source and detector. The close source, the greater number of emissions intercepted and hence

Not all of the emissions intercepted are counted. That is passes through the GM tube is counted. The GM tube efficiencies for different types of radiation.

| L3 | RADIATION SURVEY | 14 |
|---|---|---|

**FACTORS AFFECTING NET EFFICIENCY**

1. GEOMETRICAL EFFICIENCY
2. COUNTING EFFICIENCY
3. SCATTERING
4. ABSORPTION
5. RESOLVING TIME
6. BACKGROUND

2. Detection of Contamination

e. Low Level Counting (contd.)

Another significant factor affecting net efficiency is the scattering of emitted radiation. The radiation may be backscattered from the materials that the source rests on or sidescattered from materials parallel to the line joining the source and detector.

Absorption of the radiation by the sample itself can also affect the observed activity of a smear. In high level counting situations the resolving time of the GM tube can affect the observed count rate. This is the time interval between events which can be registered. For the case of counting low level smear samples the resolving time is not an important factor.

The background also affects the observed activity of a sample, but it can be easily accounted for by taking a preliminary background count for the prescribed length of time and then subtracting this background count from the observed sample count. The background count is made with radioactive sources removed from the counting area or having them properly shielded.

NET EFFICIENCY AND APPROXIMATE ACTIVITY

1. $E_N = \dfrac{C_o - B}{C_k}$

$E_N$ – NET EFFICIENCY
$C_o$ – OBSERVED COUNT
B – BACKGROUND
$C_k$ – KNOWN COUNT

2. $A_A = \dfrac{C_o - B}{E_N}$

$A_A$ – APPROXIMATE ACTIVITY

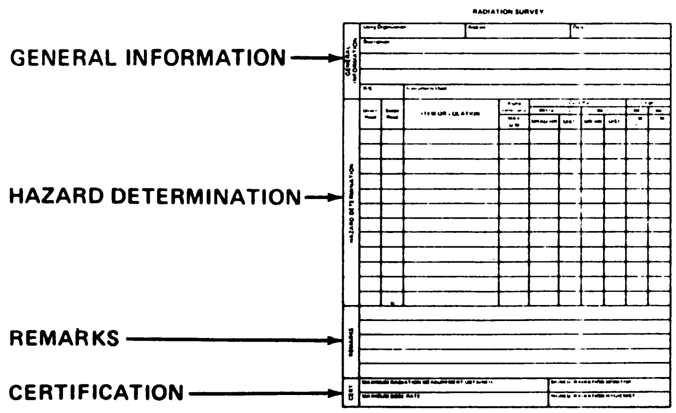
2. Detection of Contamination

e. Low Level Counting (contd.)

The effects other than background can be evaluated individually or they can be accounted for simultaneously by placing a sample of interest of known activity and observing its activity with the counting system. The net efficiency for the particular source of interest is the observed count minus the background, divided by the known count. The absolute activity of a sample of the same type of radiation is approximated by dividing its count minus the background, by the net efficiency for the particular type of radiation of interest. The counting geometry and equipment must remain constant to use net efficiency in this manner.

Since fluctuations are observed in readings, several counts of the smear should be m? and the average of these measurements can be taken as the count.

| L3 | RADIATION SURVEY | 16 |
|---|---|---|



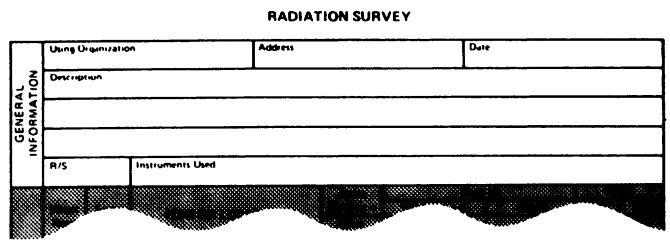

3. Recording Results

   a. Radiation Survey

      1) Introduction

         The radiation survey form provides a means of systematically evaluating and recording the different aspects of a radiation survey. The form has spaces provided for general information, hazard determination, remarks, and certification.

| L3 | RADIATION SURVEY | 17 |
|---|---|---|




3. Recording Results

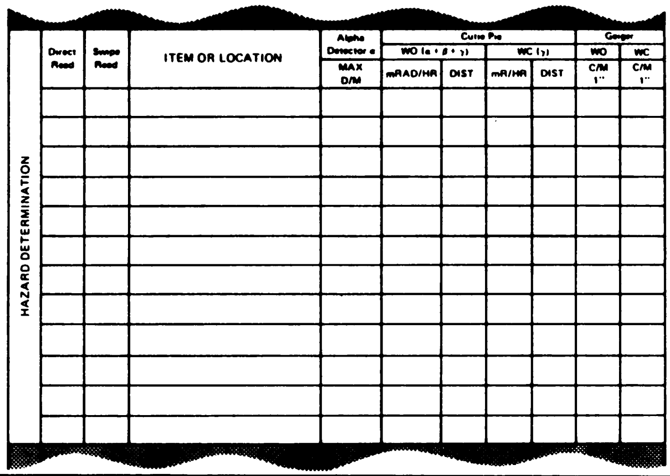
   a. Radiation Survey (contd.)

      2) General Information

         Different types of general information are recorded on the survey record in the block entitled general information.

         USING ORGANIZATION. In this space the company or the division of a company should be recorded. ADDRESS. The address of the company should be supplied in adequate detail so that someone unfamiliar with the location could find the source. DATE. The date of the survey should be recorded. DESCRIPTION. A brief description of the survey should be included. This description should tell why the survey is being made and how the source or laboratory is used. The R/S space denotes whether the survey is a routine (R) survey or a special (S) survey. The appropriate letter, R or S, is written in this space. The INSTRUMENTS USED to make the survey are also recorded. The instrument manufacturer and instrument serial number are recorded. For example, Eberline E-120 Geiger Counter (1138568), Technical Associates CP-5 Cutie Pie (18D542), etc.

| L3 | RADIATION SURVEY | 18 |
|---|---|---|



| | Direct Read | Swipe Read | ITEM OR LOCATION | Alpha Detector α | Cutie Pie | | | | Geiger | |
|---|---|---|---|---|---|---|---|---|---|---|
| HAZARD DETERMINATION | | | | | WO ($\alpha+\beta+\gamma$) | | WC ($\gamma$) | | WO | WC |
| | | | | MAX D/M | mRAD/HR | DIST | mR/HR | DIST | C/M 1" | C/M 1" |
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3. Recording Results

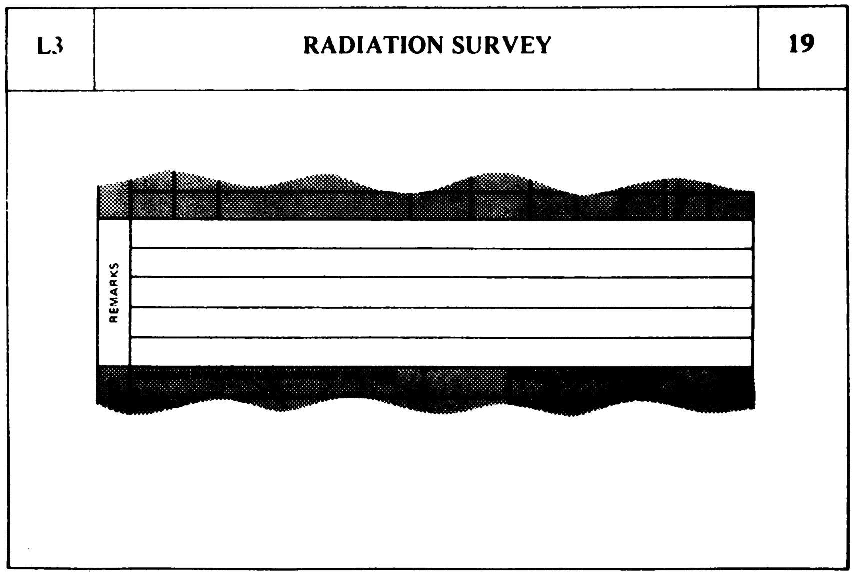
   a. Radiation Survey (contd.)

      3) Hazard Determination

The DIRECT and SWIPE columns indicate whether the reading was made directly, or of a swipe of the source. (Swipes are rough counts of Q-tips and absorbent discs made in the field using a portable survey instrument.) A check mark is placed in the column corresponding to how the reading was made. The ITEM surveyed and/or its LOCATION is recorded. The location is the location of the source within a room; not the location of the detector with respect to the source. For example, $P^{32}$ solution spilled on counter.

The readings registered on an alpha counter are entered in the ALPHA DETECTOR column. The maximum reading observed is recorded in disintegration per minute (D/M). Window open (WO) and window closed (WC) readings are made using a CUTIE PIE ionization chamber. Readings are recorded in mRAD/hr and mR/hr units. The distance, DIST., is measured from the center of the ionization chamber to the source. Open and closed window readings are also made using a GEIGER counter. Some Geiger Counter probes do not have movable windows. The same open window and closed window effects can be achieved by pointing the tube directly at the source and then turning the tube so the side wall is perpendicular to the incoming radiation. The readings obtained are reported in counts per minute (C/M). The source to detector distance is held constant at one inch.

For a side reading the distance of one inch is measured to the center of the tube.



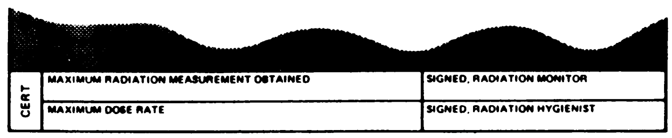

3. Recording Results

   a. Radiation Survey (contd.)

      4) Remarks

         The REMARKS block is used for summary statements regarding the survey. Action taken or recommended is noted. Names and phone numbers of individuals involved in the operation might also be recorded. If smear tests are taken, their results are noted in this space.

| L3 | RADIATION SURVEY | 20 |
|---|---|---|



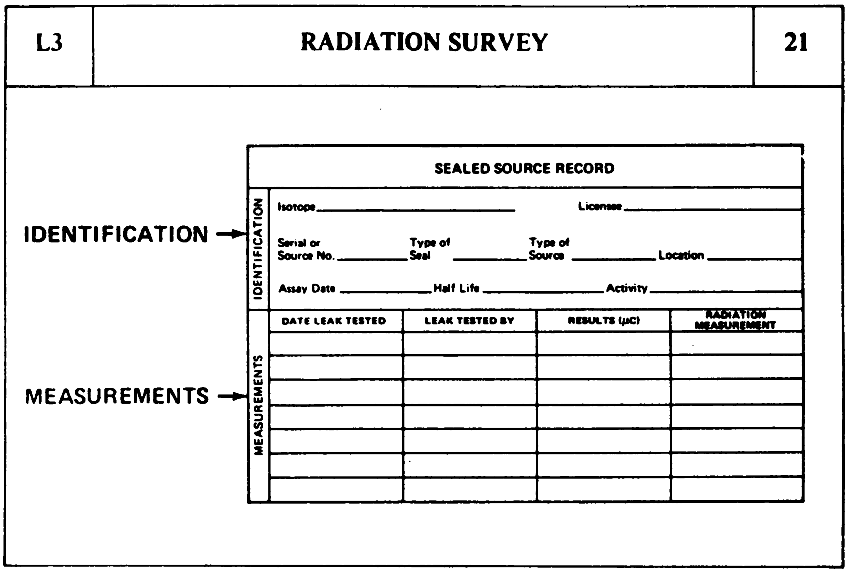

3. Recording Results

   a. Radiation Survey (contd.)

      5) Certification

      The certification block contains the MAXIMUM RADIATION MEASUREMENT OBTAINED and the MAXIMUM DOSE RATE received by personnel working in the source area. The maximum dose rate is the highest radiation rate that personnel receive. The maximum radiation measurement and the maximum dose rate may not be identical.

      Finally the survey form is SIGNED by the RADIATION MONITOR and the RADIATION HYGIENIST.




3. Recording Results (contd.)

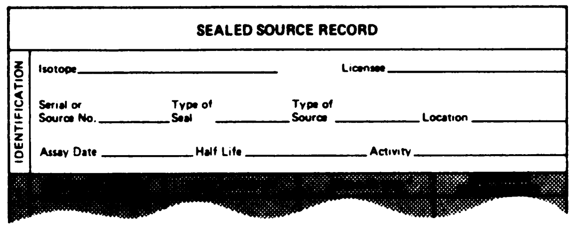
b. Sealed Sources

1) Introduction

The Sealed Source Record form provides a means of systematically recording the results of leak tests performed on a particular sealed source. This record becomes a history of the integrity of the source.

The Sealed Source Record form is divided into two segments; source identification and the record of leak measurements performed on the source.

| | | |
|---|---|---|
| L3 | RADIATION SURVEY | 22 |



SEALED SOURCE RECORD

IDENTIFICATION

Isotope ______ Licensee ______

Serial or Source No. ______ Type of Seal ______ Type of Source ______ Location ______

Assay Date ______ Half Life ______ Activity ______

3. Recording Results

b. Sealed Sources (contd.)

2) Identification

The identification segment of the record form contains information which identifies the particular source.

The ISOTOPE is entered on the form in the upper left-hand corner. Examples are $C^{14}$, $Co^{60}$, $Cs^{137}$, etc. Next the LICENSEE is recorded. This is the individual or company to whom the source has been licensed.

The SERIAL or SOURCE NO. is the number assigned to a source. This number is assigned by the licensee for bookkeeping purposes. The TYPE OF SEAL might be plastic, steel, aluminum, etc. The TYPE OF SOURCE indicates whether the source is in solid or solution form. The LOCATION of the source should be sufficient so that someone unfamiliar with the location could find the source.

The next line of information pertains to the activity of the source. The ASSAY DATE is the date when the ACTIVITY of the source was determined. The activity at a subsequent date can be determined by knowing the HALF LIFE of the source. For example;

$$A = A_o e^{-.693\ T/T_{1/2}}$$

A is the activity at T, after $A_o$ the original activity was determined. $T_{1/2}$ is the half-life of the isotope considered.

| L3 | RADIATION SURVEY | 23 |
|---|---|---|

| | DATE LEAK TESTED | LEAK TESTED BY | RESULTS ($\mu$CI) | RADIATION MEASUREMENT |
|---|---|---|---|---|
| MEASUREMENTS | | | | |
| | | | | |
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| | | | | |
| | | | | |

3. Recording Results

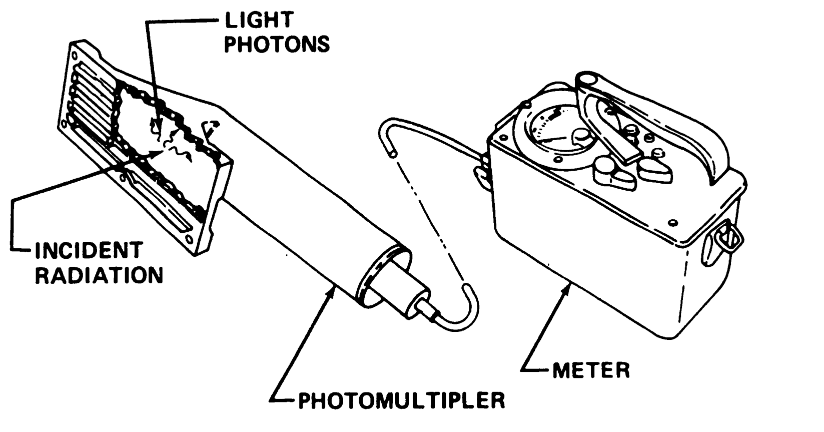
   b. Sealed Sources (contd.)

      3) Measurements

The measurements of the sealed sources are recorded in the measurements block.

The DATE LEAK TESTED, is the date when the leak test was performed. The individual making the leak test initials the column labeled LEAK TESTED BY. The RESULTS of the counting of the leak test sample are recorded in $\mu$C. The counting is performed in a scaler set-up. The last column, RADIATION MEASUREMENT, is a direct reading of the sealed source using a Cutie Pie. This measurement is made at a 2-inch source to detector distance and is reported in rad/hr. The measurement block is continued on the back of the form.

| L3 | RADIATION SURVEY | 24 |
|---|---|---|




4. Laboratory Equipment

a. Alpha Scintillation Detector

The alpha scintillation detector that will be used in today's laboratory incorporates a sensing element which does not depend upon the collection of ions for its operation. Scintillation counters depend upon a small flash of visible light that is produced when ionizing radiation interacts with a phospor or a crystal of certain substances. The magnitude of each light pulse is proportional to the energy deposited in the scintillating medium. This process of radiation interacting with certain substances to produce flashes of light called scintillations is the basis for operation of all scintillation detectors. As shown in Figure 24 the scintillations resulting from the incident radiation fall on a photomultiplier tube which converts the light pulses to electrical impulses. These electrical impulses may then be processed electronically.

| L3 | RADIATION SURVEY | 25 |
|---|---|---|

1. **SCINTILLATING MEDIA:**

   **ALPHA – SILVER ACTIVATED ZINC SULFIDE**
   **BETA – ANTHRACENE, NAPHTHALENE, STILBENE**
   **GAMMA – THALLIUM-ACTIVATED IODIDE CRYSTALS**

2. **SCINTILLATION DETECTORS:**

   **VERY SENSITIVE**
   **CAN COUNT HIGH LEVELS**

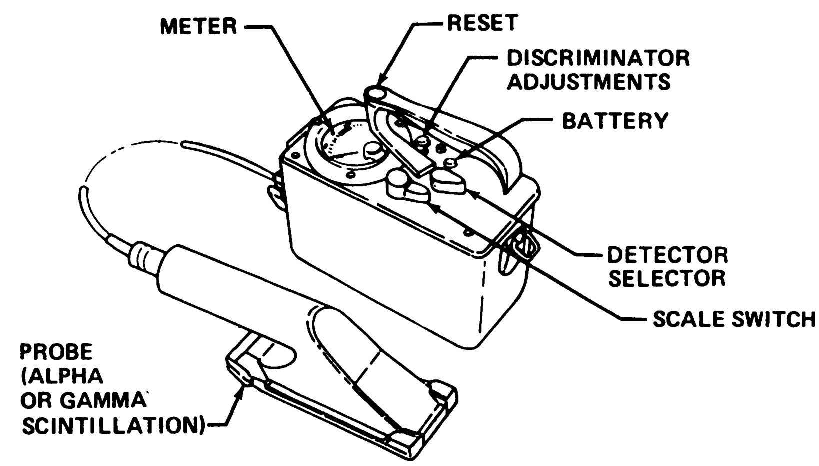
4. Laboratory Equipment

   a. Alpha Scintillation Detector (contd.)

   Different scintillation media are used for detecting different types of radiation. Some of the most common scintillation media are: silver-activated zinc sulfide for the detection of alpha radiation, anthracene, naphthalene, stilbene, and certain liquid scintillators for beta radiation and thallium-activated sodium iodide crystals for gamma detection.

   Scintillation detectors are very sensitive, more sensitive and efficient than Geiger counters, particularly to gamma radiation. They may be used to detect extremely low levels of activity. Losses due to dead time in a scintillator are very slight, as light flashes may be produced in many portions of the phosphor at the same time, and the decay time of these flashes is very short, depending on the type of phosphor. Consequently, scintillators are useful for measuring very high radiation intensities.

| L3 | RADIATION SURVEY | 26 |
|---|---|---|




4. Laboratory Equipment

   a. Alpha Scintillation Detector (contd.)

      Of the various types of scintillation detectors available, today's laboratory will use the alpha scintillation type. Figure 26 shows the Eberline alpha scintillation counter model PAC-1SAGA.

      The Scale Switch is a six position control which combines the function of turning the instrument on and selecting the desired range. The control is marked: OFF, 2r, X K, X100, X10, X1.0. To read alpha field strength, multiply the meter reading by the number indicated by the scale switch. If the scale switch is set on X10 and the meter reads 1000, the alpha field strength would be 10,000 counts per minute. The Detector Selector Switch can be set on AC-3 or PG-1, depending on which probe is being used. The AC-3 is an alpha scintillation probe and the PG-1 is a gamma scintillation detector. The Battery Check Pushbutton is depressed to check the battery. By pressing the Reset Button, the meter pointer can be rapidly zeroed after a reading has been taken. This decreases the delay due to slow meter response on the lower scale. The Discriminator Controls determine the minimum pulse size from the probe that will be counted. Two discriminator controls are provided; one for the AC-3 probe and one for the PG-1 probe.

| L3 | RADIATION SURVEY | 27 |
|---|---|---|

**DISCRIMINATOR**

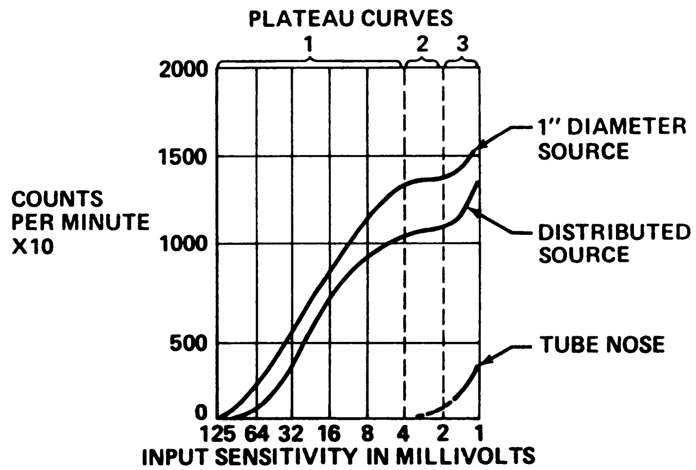
1. **CLOCKWISE ROTATION – INCREASES SENSITIVITY**
2. **COUNTER CLOCKWISE ROTATION – DECREASES SENSITIVITY**

4. Laboratory Equipment

   a. Alpha Scintillation Detector (contd.)

Recall that the pulse size is proportional to the energy deposited in the scintillator of the probe. In the presence of exceptionally high beta radiation or high gamma radiation, or when the instrument is operated at extremely high or low temperatures, it may be necessary to adjust the discriminator control. Also, should a probe be substituted, it may be necessary to adjust the discriminator control. Turning the discriminator control clockwise will make the instrument more sensitive and cause the meter reading from a source to increase. Turning the discriminator control counter clockwise will make the instrument less sensitive and cause the reading from a source to decrease.

| L3 | RADIATION SURVEY | 28 |
|---|---|---|




4. Laboratory Equipment

a. Alpha Scintillation Detector (contd.)

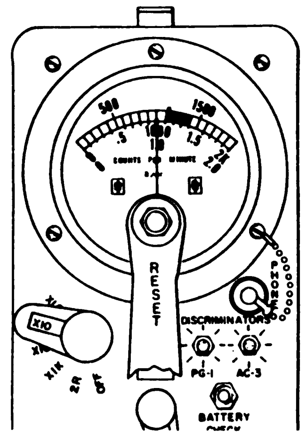
Figure 28 is a graph of counts per minute versus instrument input sensitivity (discriminator setting) with various alpha test samples. The curves are called Plateau Curves.

In Region One, the sensitivity is so low that only pulses from higher energy alpha particles are counted. Turning the discriminator in a clockwise direction causes the instrument to become more sensitive and more pulses are counted. As the discriminator setting is increased in the clockwise direction a point is reached where nearly all alpha particles are counted. This is the start of the plateau and is identified by Region Two. Turning the discriminator further causes the instrument to become so sensitive, it reads the photomultiplier tube noise; this is identified by Region Three. Optimum instrument performance is obtained by setting the discriminator for operation just before Region Three.

| L3 | RADIATION SURVEY | 29 |
| --- | --- | --- |

READING THE SCALE

1000 CPM X 10 = 10,000 CPM




4. Laboratory Equipment

   a. Alpha Scintillation Detector (contd.)

   To read alpha field strength, multiply the meter reading by the number indicated by the scale switch. If the scale switch is set on X10 and the meter reads 1000, the alpha field strength would be 10,000 counts per minute. When reading alpha activity, the meter reading must be multiplied by the number indicated by the scale switch.

| L3 | RADIATION SURVEY | 30 |
|---|---|---|

**USING THE DETECTOR**

1. **TURN SELECTOR SWITCH FROM OFF TO A SCALE POSITION, SET SELECTOR SWITCH – ALLOW WARM UP**
2. **CHECK THE BATTERY AND PLACE CHECK SOURCE UNDER PROBE**

4. Laboratory Equipment

a. Alpha Scintillation Detector (contd.)

To start the instrument, turn the selector switch from "OFF" to one of the scale positions. Set the detector switch to the probe being used. Wait a few seconds to allow the instrument to warm up. This allows the high voltage power supply to build up an adequate charge to drive the photomultiplier. Check the battery by depressing to check that the instrument is operating correctly, place the $.001 \mu Am^{241}$ check source beneath the probe face. Make sure that the probe face is clean and that no material has been inadvertently interposed between the source and the probe. The meter should read within 10% of the check source. If the instrument does not read within 10%, it should be recalibrated. If no count is obtained the batteries should be checked. Procedures for calibration and battery replacement can be found in the operator's manual.

| L3 | RADIATION SURVEY | 31 |
|---|---|---|

**USING THE DETECTOR**

3. **CARE MUST BE TAKEN NOT TO PUNCTURE PROBE FACE**
4. **PUNCTURED PROBE FACE WILL MAKE EVERYTHING APPEAR TO BE CONTAMINATED**

4. Laboratory Equipment

   a. Alpha Scintillation Detector (contd.)

Precautions must be taken so as not to set the probe down on any sharp object which might puncture the face. The probe face is extremely thin and can be punctured easily. If the probe does acquire a light leak the operator will observe that everything appears to be contaminated. To check for a light leak, alternately shadow and expose the probe face to direct light (preferably sunlight). If the meter reading changes, a light leak exists. Emergency repair or replacement of the probe face is outlined in the operator's manual.

| L3 | RADIATION SURVEY | 32 |
|---|---|---|

**USING THE DETECTOR**

5. **CONTAMINATION OF PROBE FACE CAN CAUSE ERRONEOUS READINGS**

6. **CONTAMINATION IS REMOVED BY:**

   **WATER**
   **BRUSHING**
   **CHANGING PROBE FACE**

4. Laboratory Equipment

   a. Alpha Scintillation Detector (contd.)

   Contamination of the probe occurs when radioactive material adheres to the probe face. The contamination can be invisible, but in sufficient quantities to give a reading. The contamination can generally be removed by running low pressure water over the probe face. A less desirable means of decontamination is to wipe the probe gently with clean cotton or a camel hair paint brush. If the probe cannot be decontaminated by the above methods, the probe face should be changed.

| L3 | RADIATION SURVEY | 33 |
|---|---|---|

**USING THE DETECTOR**

7. **ALPHA PARTICLES ARE EASILY STOPPED BY PAPER, DUST AND WATER**
8. **PROBE MUST BE HELD CLOSE TO THE SOURCE**

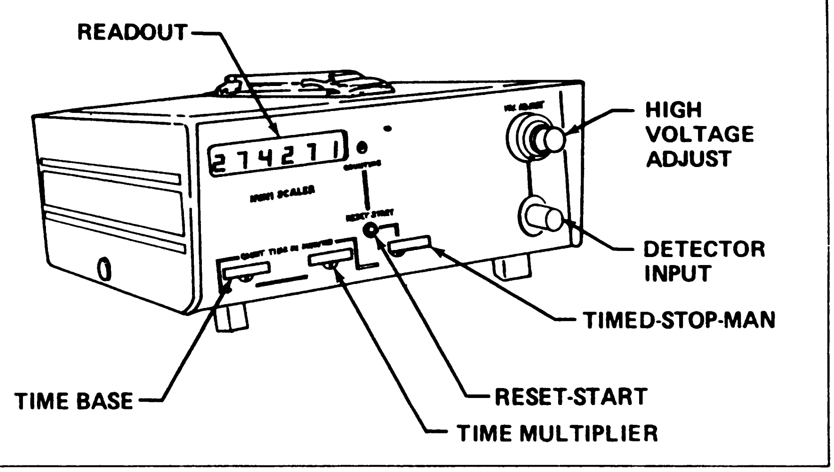
Laboratory Equipment

a. Alpha Scintillation Detector (contd.)

The operator must keep certain facts in mind when monitoring any area. A dusty or wet surface resulting from rain or dew cannot be monitored successfully. A sheet of ordinary paper the thickness of approximately .004 inch will block out nearly all alpha particles.

Another important factor is that alpha particles travel in every direction when emitted from their source. Due to the short range and radial dispersion of alpha particles the scintillation probe must be held as close to the source as possible.

| L3 | RADIATION SURVEY | 34 |
|---|---|---|




4. Laboratory Equipment (contd.)

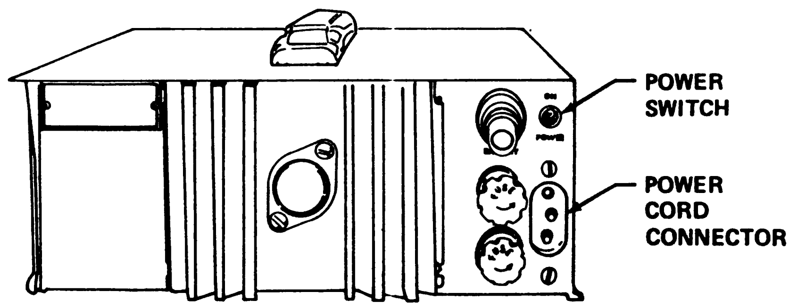
   b. Scaler

The Eberline MS-3 Mini Scaler is shown in Figure 34. The scaler consists of a variable high voltage supply, a charge sensitive input amplifier, a six decade scaler, and a timer.

The High Voltage Adjust is a ten turn calibrated dial used for setting and changing the high voltage. The voltage can be adjusted from approximately 200 volts to 2500 volts. The Detector Input accepts the coaxial connector from a detector. The Timed-Stop-Man switch selects the mode of operation. The manual (MAN) mode causes the scaler to count continuously until the switch is set to the stop position. In the stop position the scaler does not count. In the timed position the scaler automatically stops counting after the preset time has been reached.

The preset time is determined by setting the Time Base to 1, 2 or 5. The Time Multiplier is then set at .1, 1 or 10. The preset time is simply the time base setting multiplied by the time multiplier setting. The count is displayed on a 6 digit LED Readout. The Readout is cleared by depressing the Reset-Start button. Count is resumed or started by depressing the Reset-Start button.

| | | |
|---|---|---|
| L3 | RADIATION SURVEY | 35 |




4. Laboratory Equipment

   b. Scaler (contd.)

      The Power Switch is located on the back panel of the scaler. The Power Cord Connector is also located on the back panel.

| L3 | RADIATION SURVEY | 36 |
|---|---|---|

**USING THE SCALER**

1. **WITH POWER OFF, CONNECT PROBE**
2. **ZERO H.V. CONTROL – TURN POWER ON – ALLOW WARM UP**
3. **TIMED-STOP-MAN SWITCH TO STOP – DEPRESS RESET BUTTON**
4. **SET HIGH VOLTAGE TO PROPER OPERATING VOLTAGE**

4. Laboratory Equipment

b. Scaler (contd.)

The instructor will explain the proper turn on and use of the scaler.

1) If GM tube detector has not been connected to the scaler, turn power switch to OFF position and attach the detector cable to the connector labelled DETECTOR.

2) Turn H.V. control fully counterclockwise. Turn power switch to ON position. Allow for warmup.

3) Turn Timed-Stop-Man switch to Stop. Depress RESET button until scaler reads zero.

4) Carefully set HIGH VOLTAGE controls to proper operating voltage level for the GM tube being used. This setting will be determined by the instructor previous to the lab. The students will determine the proper operating voltage during their exercise. To determine high voltage setting see instructions on "Determination of Plateau Curve". Do not attempt to set the high voltage unless you have secured the proper value by following the required procedure.

| L3 | RADIATION SURVEY | 37 |
|---|---|---|

**USING THE SCALER**

5. **PLACE RADIOACTIVE SOURCE ON GM TUBE STAND**
6. **TIMED-STOP-MAN SWITCH TO MAN. DEPRESS START BUTTON. OR SET TIME BASE AND TIME MULTIPLIER. SET TIMED-STOP-MAN SWITCH TO TIMED. DEPRESS START BUTTON**
7. **ZERO HV CONTROL. TURN POWER OFF IF USAGE IS COMPLETE**

4. Laboratory Equipment

b. Scaler (contd.)

5) Place a radioactive sample in position on GM tube stand.

6) Place Timed-Stop-Man switch in Man position. Press Start Button. At end of desired time interval, return Timed-Stop-Man Switch to Stop position. If timer is used, set Time Base and Time Multiplier for desired time. Place Timed-Stop-Man Switch to Timed and depress Start Button. (Total counts divided by number of minutes of counting equals activity in counts per minute.)

7) If the scaler is used frequently, turn off all switches except POWER switch at the end of the experiment (be sure to turn HV control to zero). If the scaler is used only once or twice a week, turn off all switches including the POWER switch.

| L3 | RADIATION SURVEY | 38 |
|---|---|---|

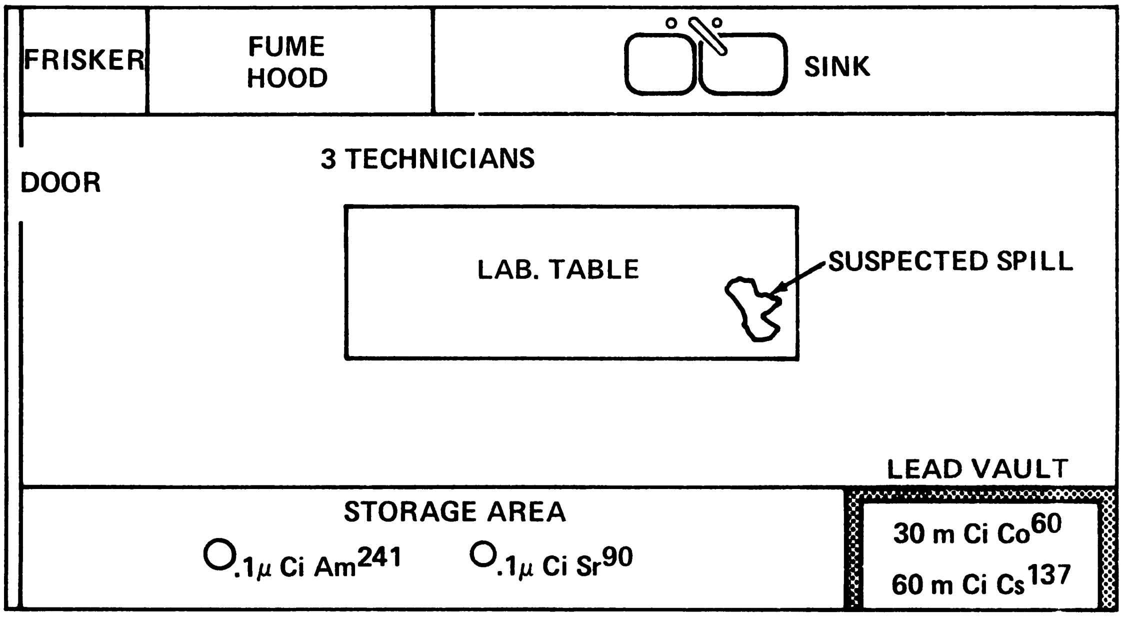
**STUDENTS' LABORATORY EXERCISE**

| | |
|---|---|
| PHASE I. | RADIATION SURVEY<br>ALPHA, BETA, GAMMA SOURCES |
| PHASE II. | LOW LEVEL COUNTING<br>GEIGER PLATEAU<br>COUNT SMEAR AND LEAK SAMPLES |

## C. STUDENTS' LABORATORY EXERCISE

### 1. Introduction

The students' laboratory will be conducted in two phases. In Phase I the students will make direct readings of $\alpha$, $\beta$ and $\gamma$ sources using alpha scintillation, Cutie Pie, and Geiger detectors. Results will be reported on a Radiation Survey form. Smear and leak tests will also be made on some of the sources.




2. Phase I. Making a Radiation Survey

   a. Alpha Source

      1) Suppose that you are requested to make a survey of the radioisotope lab at the Radiation Effects Laboratory. The lab is located at 1422 South Trenton Street, Seattle, Washington. The survey is requested because an alpha source is suspected to be leaking. Since you are going to the lab you decide to check other sealed sources in the lab (parts b and c below). These sources are used for material testing and are located in the lab as shown in Figure 39. There are people working in the laboratory as shown.

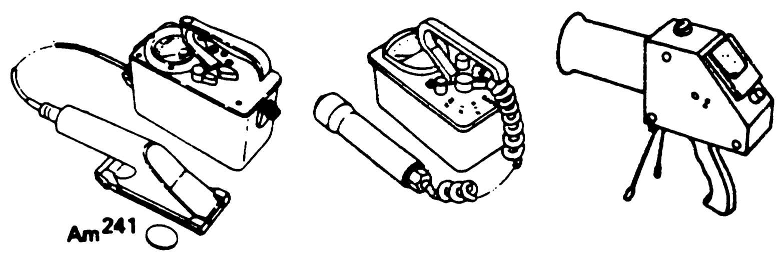
         You enter the lab with your C.P. zeroed, ready for use, and determine that the laboratory has a safe background level. Then it is safe for you to work in the lab as you check for contamination and leaks.

         Assume the readings you are about to make are made at the locations shown in Figure 39.

      2) Wearing gloves, a lab coat, and with the equipment set-up as shown in Figure 40; make direct readings of the $.1\mu$Ci $Am^{241}$ alpha source. Use the alpha scintillation detector, the Cutie Pie, and the Geiger Counter. Make the readings as required by the survey form of Figure 44. The values obtained are recorded on this survey form.

| L3 | RADIATION SURVEY | 40 |
|---|---|---|

**READING $Am^{241}$ ALPHA SOURCE**




**CAUTION – NEVER DIRECTLY TOUCH AN ALPHA SOURCE WITH A PROBE OR ANY OBJECT. DO NOT ALLOW BODY CONTACT**

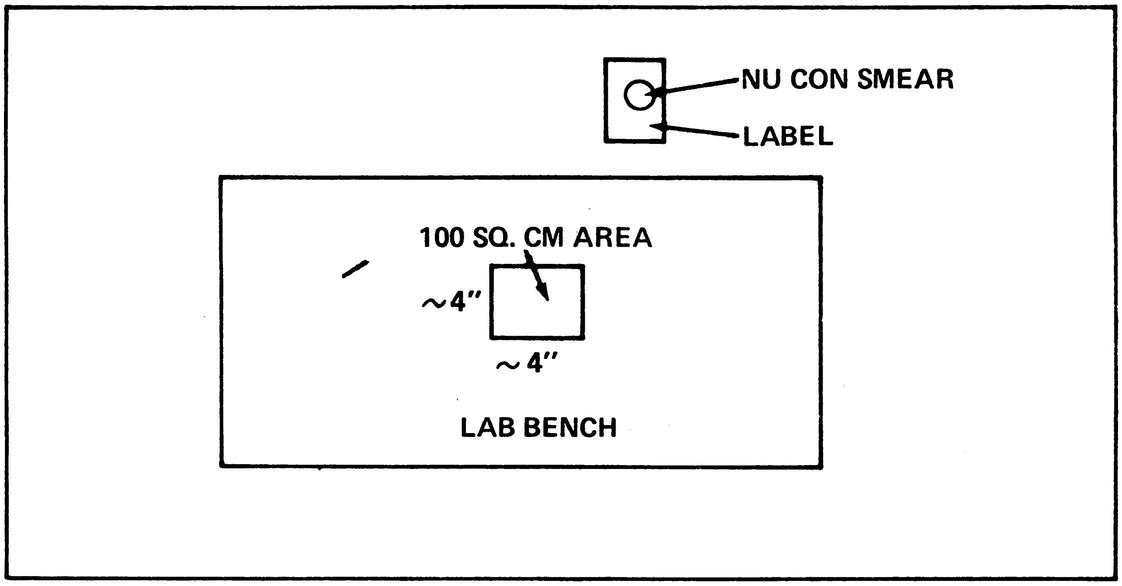
2. Phase I. Making a Radiation Survey

   a. Alpha Source (contd.)

      3) To use the alpha detector, turn the selector switch from "OFF" to one of the scale positions. Turn the detector selector switch to AC-3 and check the battery. Wait a few seconds to allow the instrument to warm up. To check that the instrument is operating correctly, place the .001$\mu$Ci $Am^{241}$ check source beneath the probe face. Make sure that the probe face is clean and that no material has been inadvertently interposed between the source and the probe. The meter should read within 10% of the check source.

      For optimum setting of the discriminator control, turn the discriminator control clockwise until approximately 100 counts per minute are indicated on the X10 scale with no source in front of the probe. Then place the check source into the active position and turn the discriminator control counter clockwise until the reading decreases approximately 5%. Lock the discriminator control. NOTE: Conditions may exist when no photomultiplier noise can be detected. If this occurs, lock potentiometer at maximum clockwise position.

SMEAR TEST




2. Phase I. Making a Radiation Survey

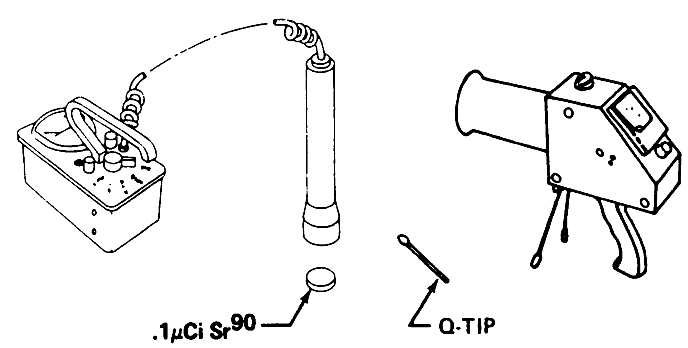
   a. Alpha Source (contd.)

      4) Make a smear of your lab bench. Use a dry Nu-Con smear for this purpose. Present this smear to the GM detector. Record the reading on Figure 44. Place a check in the swipe column. Next, place the self adhesive Nu-Con smear on a label. Put a number on the label, the date, time, location of where the smear was taken and sign your name. Place this smear in a plastic bag for counting later in the lab.

         Assume that you detected $Am^{241}$ alpha contamination at this location using your GM and alpha scintillation detector. For the purpose of this lab; the smear you make corresponds to the spill shown in Figure 39.

| L3 | RADIATION SURVEY | 42 |
|---|---|---|

**READING OF $Sr^{90}$ BETA SOURCE**




2. Phase I. Making a Radiation Survey (contd.)

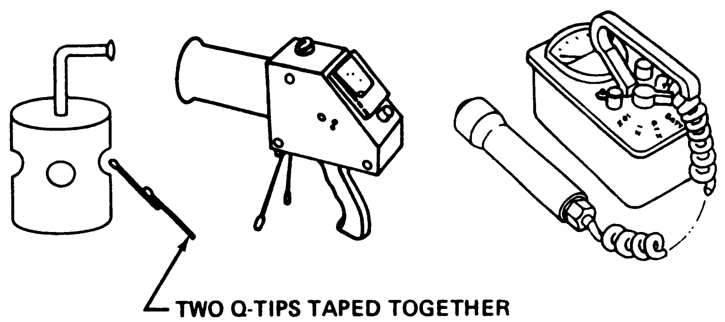
   b. Beta Source

      1) With the equipment set-up as shown in Figure 42 make direct readings on the .1μCi $Sr^{90}$ beta source. Use the Cutie Pie and the Geiger Counter. Make the readings required by the survey form. The values obtained are recorded on Figure 44.

      2) Next make a leak test of the $Sr^{90}$ beta source. Use a dry Q-tip for this purpose. Present the Q-tip to the G.M. Record the readings on Figure 44. Again the swipe column is checked. Place the Q-tip in a plastic bag. Label the bag with a number, the date, time, location of leak test, and sign your name. This Q-tip will be counted later in the lab.

| L3 | RADIATION SURVEY | 43 |
|---|---|---|

**READING THE Co 60 GAMMA SOURCE**




2. Phase I. Making a Radiation Survey (contd.)

   c. Gamma Source

      1) Repeat steps 1) and 2) of part b. Use the 30mCi$^{60}$Co gamma source instead of the .1$\mu$Ci$^{90}$Sr beta source. The equipment set-up for part c is shown in Figure 43. Since the gamma source has a high activity, it will not be directly leak tested. The source should be in its shielded position. The leak test will be performed by wiping the port with two Q-tips taped together. In this manner the student making the leak test will not be exposed to high radiation levels.

## RADIATION SURVEY

**GENERAL INFORMATION**

| Using Organization | Address | Date |
|---|---|---|
| Description | | |
| | | |
| | | |
| R/S | Instruments Used: | |

**HAZARD DETERMINATION**

| Direct Read | Swipe Read | ITEM OR LOCATION | Alpha Detector $\alpha$ | Cutie Pie | | | | Geiger | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | WO $(\alpha + \beta + \gamma)$ | | WC $(\gamma)$ | | WO | WC |
| | | | MAX D/M | mRAD/HR | DIST. | mR/HR | DIST. | C/M 1" | C/M 1" |
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**REMARKS**

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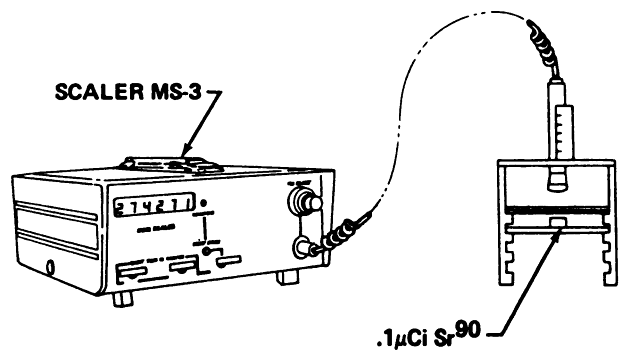
| |

**CERT**

| MAXIMUM RADIATION MEASUREMENT OBTAINED | SIGNED, RADIATION MONITOR |
|---|---|
| MAXIMUM DOSE RATE | SIGNED, RADIATION HYGIENIST |

| L3 | RADIATION SURVEY | 45 |
|---|---|---|

DETERMINATION OF GEIGER PLATEAU




3. Phase II. Low Level Counting

   a. Determination of Geiger Plateau

      1) Set-up the equipment as shown in Figure 45.

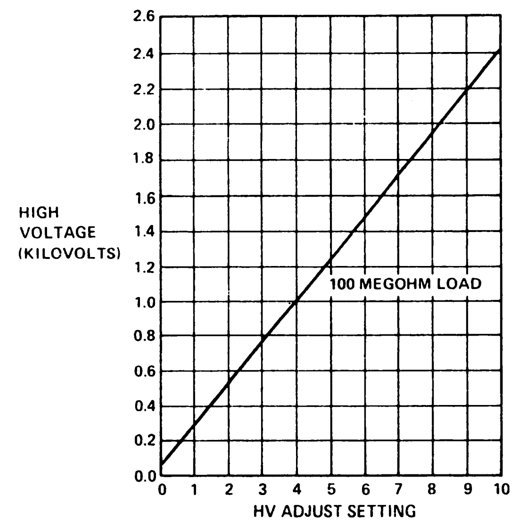
      2) Turn the power switch of the scaler to the OFF position.

      3) Connect the GM tube cable to the input receptacle on the scaler.

      4) Always set the H.V. control fully counterclockwise to ensure against damage to the detector.

      5) Turn power switch to ON.

      6) Place the $.1 \mu Ci Sr^{90}$ source in position on the tube stand.




3. Phase II. Low Level Counting

   a. Determination of Geiger Plateau (contd.)

      7) Find the "starting potential" by increasing the H.V. control until activity is first registered on the scaler.

      8) Use Figure 47 to record the data, and Figure 46 to determine the voltage to scale setting conversion.

      9) Beginning with a voltage setting of 100 volts below the starting potential, count for a one minute period.

      10) Increase high voltage 100 volts, reset the scaler and repeat counting procedure. Continue to take counts, increasing the voltage by 100 volts each time you count.

      11) Before very many counts have been taken, a trend will become evident, in that the count rate will be varying very little for each increase in voltage. It is only necessary to count long enough to assure that you are located in the voltage range where increases in voltage affect count rates very little. At this point, stop counting, because further increases in voltage will only damage the GM tube.

      12) Plot the detector plateau curve, using the values recorded on your data table. Use Figure 48 for this purpose.

      13) Locate the threshold (start) of the plateau on your graph. The proper operating voltage would then be 100 volts above the voltage represented at the threshold of the plateau.

## COUNT RATE AS A FUNCTION OF TUBE VOLTAGE

| HIGH VOLTAGE SETTING | TOTAL COUNTS | TIME (MINUTES) | COUNTS PER MINUTE $CPM = \frac{\text{TOTAL COUNTS}}{\text{MINUTES}}$ |
|---|---|---|---|
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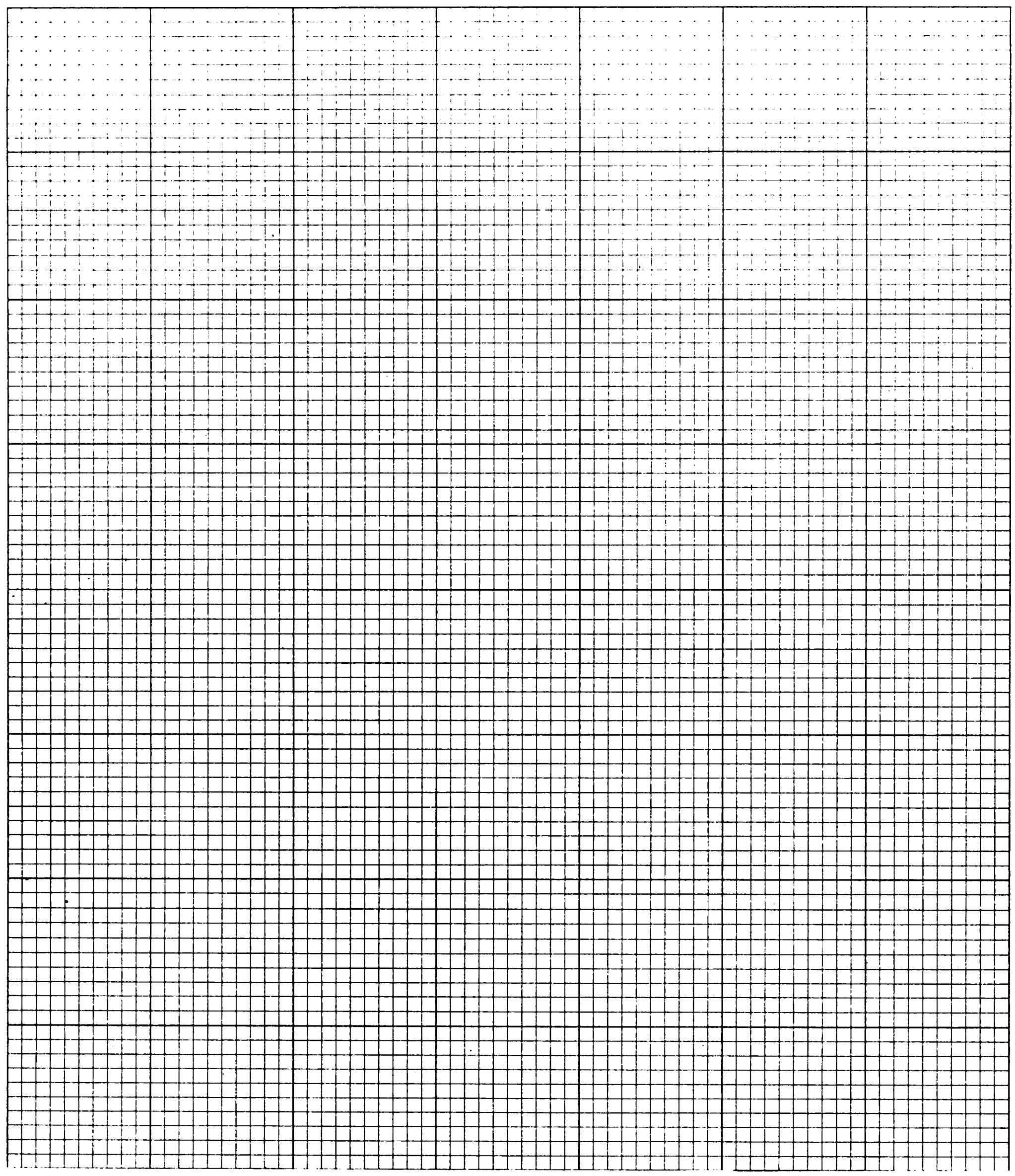
## COUNT RATE AS A FUNCTION OF TUBE VOLTAGE

CPM



HIGH VOLTAGE SETTING

3. Phase II. Low Level Counting (contd.)

b. Counting of Alpha Smear

1) The net effeciency of the scaler set-up for an alpha source must be determined. This can be accomplished by using the $.1\mu Ci\ Am^{241}$ standard source.

Place the $Am^{241}$ standard source on the counting stand and count for five minutes. The source to detector distance should be ~1/8". The G-M tube is operated at the plateau voltage determined in Phase II part a. Record results on Figure 49.

2) Next obtain a five minute background count. Record results on Figure 49.

3) Determine the net efficiency using the following relation

$$E_N = \frac{Co\text{-}B}{C_K}$$

when $E_N$ = net efficiency

Co = observed count (CPM)

B = background (CPM)

$C_K$ = known count (CPM)

Use Figure 49 for your calculation.

4) Determine the activity of the alpha smear, taken in Phase I. This is done by placing the smear on the counting stand (maintaining the same geometry as was used to determine the net efficiency) and making a five minute count. The activity is then given by

$$A_A = \frac{Co\text{-}B}{E_N}$$

where $A_A$ = approximate activity (CPM)

Co = observed count (CPM)

B = background (CPM)

Use Figure 49 for your calculation. Record results on Figure 44 (given in $CPM/100\ cm^2$)

5) Place Nu-Con smear in a radioactive waste container when finished counting.

CALIBRATION SOURCE ______________________________
KNOWN ACTIVITY ____________ CPM
SOURCE TO DETECTOR DISTANCE ______________ INCHES

5 MIN COUNT (CALIB SOURCE) $\dfrac{\_\_\_\_\_\_\_\_}{5\ \text{MIN}}$ = __________ CPM

5 MIN BACKGROUND COUNT $\dfrac{\_\_\_\_\_\_\_\_}{5\ \text{MIN}}$ = __________ CPM

5 MIN COUNT (SMEAR) $\dfrac{\_\_\_\_\_\_\_\_}{5\ \text{MIN}}$ = __________ CPM

NET EFFICIENCY FOR ________________________________

$$E_N = \frac{C_o - B}{C_k} =$$

APPROXIMATE ACTIVITY OF ___________________________

$$A_A = \frac{C_o - B}{E_N} =$$

3. Phase II. Low Level Counting (contd.)

c. Counting of Beta Leak Test

1) Determine the net-efficiency of the scaler set-up for a $Sr^{90}$ beta source. Use the $.1\mu Ci$ $Sr^{90}$ standard source for this purpose. Again the voltage is set at the plateau voltage as above. Source to detector distance is ~1". Record data on Figure 50.

2) Determine the activity of the Beta Leak Test taken in Phase I. This is done by placing the Q-tip on the counting stand (maintaining the same geometry as was used to determine the net efficiency) and making a five minute count.

   Use Figure 50 for your calculation and report results on Figure 51 (in $\mu Ci$).

3) Place the Q-tip in a radioactive waste container when finished counting.

d. Counting of Gamma Leak Test

1) Determine the net-efficiency of the scaler set-up for a $Co^{60}$ gamma source. Use the $.3\mu Ci$ $Co^{60}$ standard source for this purpose. Record data on Figure 52.

2) Determine the activity of the Gamma Leak Test taken in Phase I. Use Figure 52 for your calculation and report results on Figure 53 (in $\mu Ci$).

3) Place the Q-tip in a radioactive waste container when finished counting.

CALIBRATION SOURCE ______________________
KNOWN ACTIVITY __________ CPM
SOURCE TO DETECTOR DISTANCE __________ INCHES

5 MIN COUNT (CALIB SOURCE) $\dfrac{\rule{3cm}{0.4pt}}{5\ MIN}$ = __________ CPM

5 MIN BACKGROUND COUNT $\dfrac{\rule{3cm}{0.4pt}}{5\ MIN}$ = __________ CPM

5 MIN COUNT ($\beta$ LEAK) $\dfrac{\rule{3cm}{0.4pt}}{5\ MIN}$ = __________ CPM

NET EFFICIENCY FOR ______________________________

$$E_N = \frac{C_o - B}{C_k} =$$

APPROXIMATE ACTIVITY OF ______________________________

$$A_A = \frac{C_o - B}{E_N} =$$

## SEALED SOURCE RECORD

IDENTIFICATION

Isotope ______________ Licensee ______________

Serial or Source No. ______ Type of Seal ______ Type of Source ______ Location ______

Assay Date ______ Half Life ______ Activity ______

MEASUREMENTS

| DATE LEAK TESTED | LEAK TESTED BY | RESULTS (μC) | RADIATION MEASUREMENT |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
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| | | | |
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| | | | |

CALIBRATION SOURCE ____________________
KNOWN ACTIVITY __________ CPM
SOURCE TO DETECTOR DISTANCE __________ INCHES

5 MIN COUNT (CALIB SOURCE) $\dfrac{\_\_\_\_\_\_\_\_\_\_}{5\ \text{MIN}}$ = __________ CPM

5 MIN BACKGROUND COUNT $\dfrac{\_\_\_\_\_\_\_\_\_\_}{5\ \text{MIN}}$ = __________ CPM

5 MIN COUNT ($\gamma$ LEAK) $\dfrac{\_\_\_\_\_\_\_\_\_\_}{5\ \text{MIN}}$ = __________ CPM

NET EFFICIENCY FOR ____________________

$$E_N = \frac{C_o - B}{C_k} =$$

APPROXIMATE ACTIVITY OF ____________________

$$A_A = \frac{C_o - B}{E_N} =$$

## SEALED SOURCE RECORD

**IDENTIFICATION**

Isotope ____________________ Licensee ____________________

Serial or Source No. __________ Type of Seal __________ Type of Source __________ Location __________

Assay Date __________ Half Life __________ Activity __________

**MEASUREMENTS**

| DATE LEAK TESTED | LEAK TESTED BY | RESULTS ($\mu$C) | RADIATION MEASUREMENT |
|---|---|---|---|
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# LABORATORY NO. 4
# RADIOGRAPHY SURVEY

COURSE OUTLINE

IV. RADIOGRAPHY SURVEY

A. INTRODUCTION

1. Objectives

2. Overview

3. Equipment

4. Precautions

B. INSTRUCTOR'S DEMONSTRATION - LECTURE

1. Introduction

2. Production of X-Rays

3. Effects of Tube Parameters on X-Ray Spectra

4. Radiography Survey Form

a. Introduction
b. General Information
c. Approved Ranges
d. Operating Limitations
e. Monitoring Devices
f. Certification
g. Distribution
h. Measurements
i. Personnel Protection
j. Remarks and Layout

C. STUDENTS' LABORATORY EXERCISE

1. Introduction

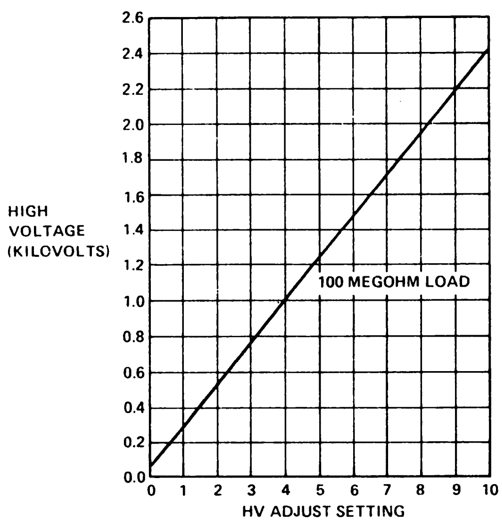
2. Phase I. Survey of an X-Ray Installation

a. Preparation

b. X-Ray Machine Survey

3. Phase II. Variation of Machine Parameters

a. Tube Current
b. Tube Voltage
c. Filtration




3. Phase II. Low Level Counting

a. Determination of Geiger Plateau (contd.)

7) Find the "starting potential" by increasing the H.V. control until activity is first registered on the scaler.

8) Use Figure 47 to record the data, and Figure 46 to determine the voltage to scale setting conversion.

9) Beginning with a voltage setting of 100 volts below the starting potential, count for a one minute period.

10) Increase high voltage 100 volts, reset the scaler and repeat counting procedure. Continue to take counts, increasing the voltage by 100 volts each time you count.

11) Before very many counts have been taken, a trend will become evident, in that the count rate will be varying very little for each increase in voltage. It is only necessary to count long enough to assure that you are located in the voltage range where increases in voltage affect count rates very little. At this point, stop counting, because further increases in voltage will only damage the GM tube.

12) Plot the detector plateau curve, using the values recorded on your data table. Use Figure 48 for this purpose.

13) Locate the threshold (start) of the plateau on your graph. The proper operating voltage would then be 100 volts above the voltage represented at the threshold of the plateau.

## COUNT RATE AS A FUNCTION OF TUBE VOLTAGE

| HIGH VOLTAGE SETTING | TOTAL COUNTS | TIME (MINUTES) | COUNTS PER MINUTE $CPM = \frac{\text{TOTAL COUNTS}}{\text{MINUTES}}$ |
|---|---|---|---|
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| L4 | RADIOGRAPHY SURVEY | 1 |
|---|---|---|

**OBJECTIVES**

1. REVIEW BASIC PROPERTIES AND PRODUCTION OF X-RAYS
2. MAKE A SURVEY OF AN X-RAY INSTALLATION
3. VARY MACHINE PARAMETERS AFFECTING X-RAY SPECTRA

# IV. RADIOGRAPHY SURVEY

## A. INTRODUCTION

1. Objectives

   a. To review the basic properties and production of x-rays.

   b. To make a survey of an x-ray installation.

   c. To vary machine parameters affecting x-ray spectra.

2. Overview

   The instructor will begin the laboratory by stating the objectives, pointing out the equipment and reviewing the precautions to be followed.

   Next basic properties and production of x-rays will be discussed. A radiography survey form will be presented and explained.

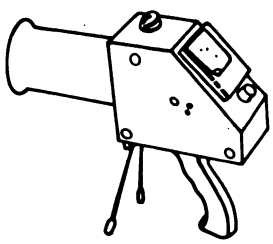
   The students' during their laboratory exercise will make a survey of an x-ray installation.

   A radiography survey form will be completed. The x-ray machine's operating parameters will be varied to observe changes in spectra.

| L4 | RADIOGRAPHY SURVEY | 2 |
|---|---|---|

## EQUIPMENT

1. X-RAY MACHINE
2. CUTIE PIE



3. Equipment List

   a. X-ray Machine

   b. Cutie Pie Ionization Chamber
   Technical Associates CP-5 with AC-3 probe

   c. .5mm Al sheets

   d. Pocket Dosimeter–Victoreen 541A
   Pocket Dosimeter Charger–Victoreen 2000A

   e. Film Badge, Finger Ring

   f. Large Lead Shields

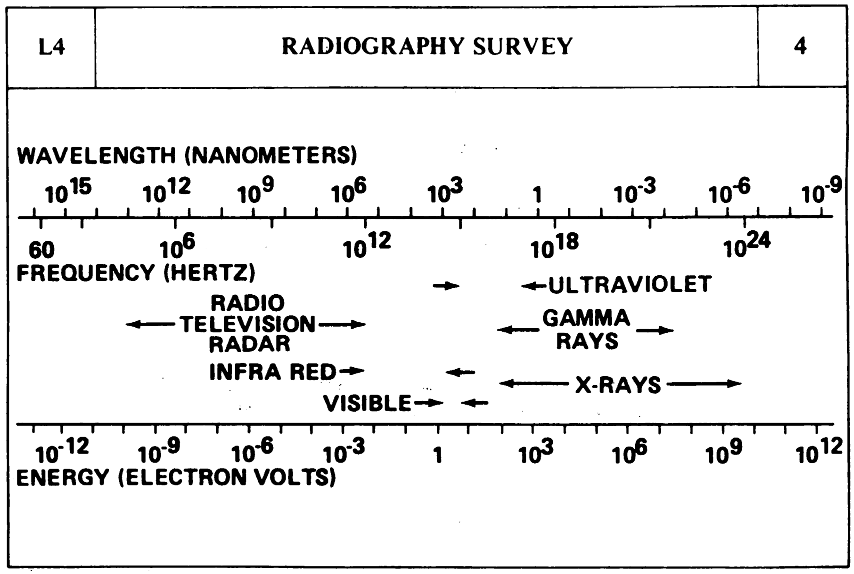
| L4 | RADIOGRAPHY SURVEY | 3 |
|---|---|---|

**PRECAUTIONS**

1. DO NOT ENTER DESIGNATED HAZARDOUS AREAS
2. AVOID UNNECESSARY EXPOSURE
3. WEAR A FILM BADGE, FILM RING AND A POCKET DOSIMETER AT ALL TIMES

4. Precautions

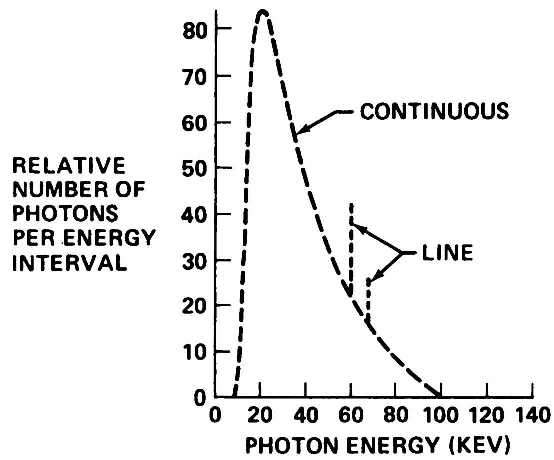
These precautions will be followed during the demonstration and during the students' laboratory exercise.




## B. INSTRUCTOR'S DEMONSTRATION – LECTURE

### 1. Introduction

X-rays were discovered in 1895 by Roentgen. They are a part of the electromagnetic spectrum which propagates through vacuum at 3 x $10^8$ m/s. The entire electromagnetic spectrum can be divided into various sections depending on frequency, wavelength or energy, as shown in Figure 4. The divisions are somewhat arbitrary. For example; x-rays and gamma rays are for historical reasons distinguished, on the basis of their origin, and not particularly on the basis of their energy. Gamma rays are emitted from the nucleus of an atom when the nucleus undergoes a transition from a higher to a lower energy level. X-rays, on the other hand, are produced by atomic de-excitation and electron acceleration.




2. Production of X-Rays

X-rays are produced by bombarding a material with energetic electrons. These electrons lose energy by one or more of three processes:

a. Interaction with the orbital electrons of target atoms, causing their ionization,

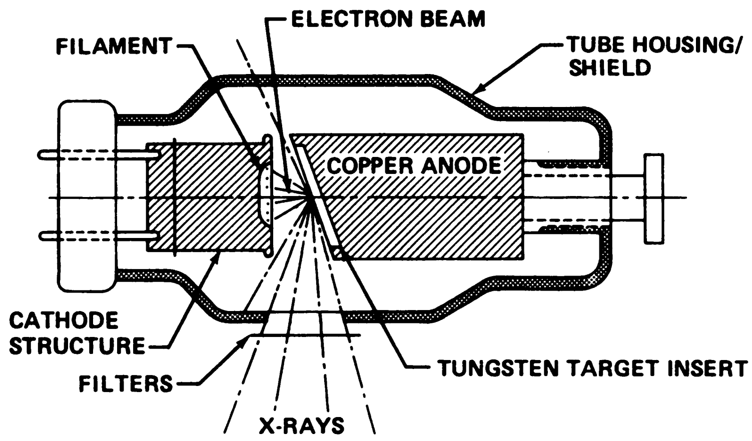
b. Interaction with the orbital electrons of target atoms, causing their excitation,

c. Interaction with the coulomb field of target nuclei, resulting in bremsstrahlung (German for "braking radiation").

The first two processes produce photons (called characteristic x-rays) of discrete energies, giving rise to a sharp line spectrum superimposed on the continuous spectrum. The number of photons in the line spectrum from an x-ray machine with a tungsten target operating at 100 keV (constant potential) constitutes about ten percent of the total photon spectrum.

The third process gives rise to photons of a continuous range of energies. As mentioned, the radiation resulting from this process is called bremsstrahlung.

| L4 | RADIOGRAPHY SURVEY | 6 |
| --- | --- | --- |




2. Production of X-Rays (contd.)

A practical x-ray generator utilizes the three ways in which x-rays are produced. Such a generator requires:

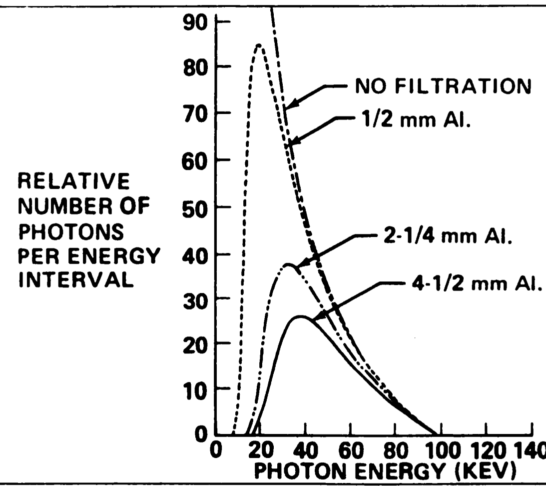
a. A source of electrons-usually a heated tungsten filament.

b. A source of high voltage to impart high energies to the electrons.

c. A target for the electrons to strike, so their velocity can be changed abruptly.

A typical x-ray tube is shown in Figure 6. The filament at the cathode provides the necessary electrons. These electrons are then accelerated to the anode where they strike a tungsten target. The x-rays are produced by the interaction of the energetic electrons with the target material. The tube housing is a shield which permits the x-rays to escape in the direction desired. The x-rays emitted may be filtered with aluminum absorbers.

| | | |
|---|---|---|
| L4 | RADIOGRAPHY SURVEY | 7 |




3. Effects of Tube Parameters On X-Ray Spectra

The curves in Figure 7 show the effects of adding different amounts of filtration. (The line spectra has been omitted for clarity.) As more aluminum is added, the average photon energy increases, but the total number of photons in the useful beam is reduced.

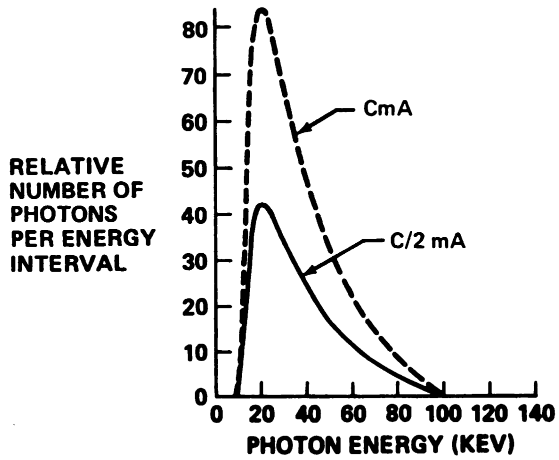
This effect can be understood by considering the attenuation of a beam of x-ray photons passing through an absorber. The intensity of passed x-ray photons can be described by:

$$I = I_o e^{-\mu x}$$

where $I_o$ represents the number of photons/cm$^2$ in the primary beam and I represents the number of photons/cm$^2$ remaining in the beam after passing through an absorber of thickness, x.

The linear attenuation coefficient, $\mu$, depends on the material of the absorber and the energy of the incident photons. Since $\mu$ becomes smaller as the photon energy increases, the low-energy part of the continuous spectrum is more effectively attenuated by the absorber than is the high-energy part of the spectrum. Although the resulting photon beam is reduced in intensity, it is shifted to a higher average photon energy by the selective attenuation.

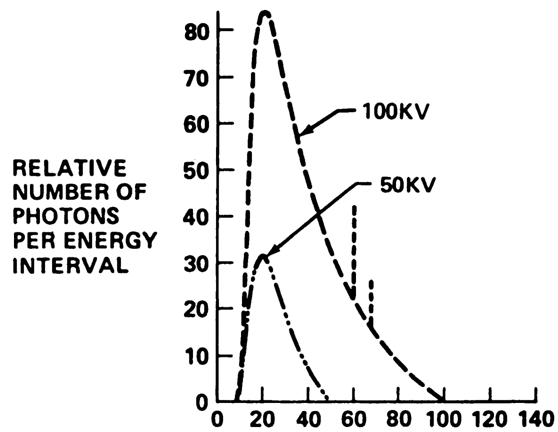
| L4 | RADIOGRAPHY SURVEY | 8 |
|---|---|---|




3. Effects of Tube Parameters on X-Ray Spectra (contd.)

Another variable machine parameter is tube current (number of electrons impinging on the target per unit time.) It is usually measured in milliamperes (mA). The effect on the x-ray spectrum of changing tube current from an arbitrary amount (C mA) to half that amount (C/2 mA), while holding the tube voltage constant at 100 kV and the filtration at 0.5 mm Al, is shown in Figure 8. (The line spectra has been omitted for clarity.) The spectral shape does not change; only the number of photons delivered at each energy differs, by a factor of 2.

| L4 | RADIOGRAPHY SURVEY | 9 |
|---|---|---|



EFFECT OF KV CHANGE

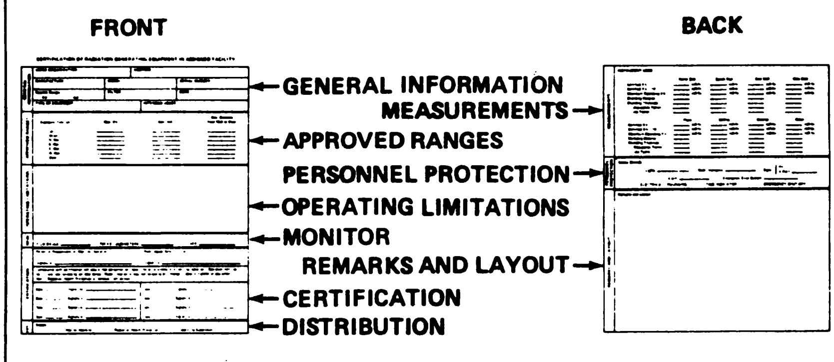
3. Effects of Tube Parameters on X-Ray Spectra (contd.)

A third variable machine parameter is the electric potential across the x-ray tube. This potential, usually measured in kilovolts, determines the energy the electrons have when they arrive at the target. Figure 9 shows the effect of increasing the potential from 50 kV to 100 kV while keeping the current fixed and the filtration the same 0.5 mm Al. It is observed that the tungsten K characteristic x-rays do not appear in the 50 kV spectrum, but are present in the 100 kV spectrum. About 69.5 keV are necessary to remove a K electron from a tungsten atom; at 50 kV not enough energy is available.

Ideally, when V is doubled, the number of bremsstrahlung photons produced is doubled. In actual practice, however, this 2:1 ratio does not hold. If any filtration is present (as it always is for practical x-ray tubes), the ratio is larger than for the idealized case, because the lower kV ideal spectrum contains a greater percentage of very low energy photons which are easily removed by filtration. For example, as shown in Figure 9, the ratio between the area under the 100 kV spectrum and the area under the 50 kV spectrum, each with 0.5 mm Al, is about 4:1. As the filtration is increased further, the ratio between the two areas continues to increase.

In summary, increasing the accelerating voltage will increase the x-ray energy and the intensity.

| L4 | RADIOGRAPHY SURVEY | 10 |
|---|---|---|




4. Radiography Survey Form

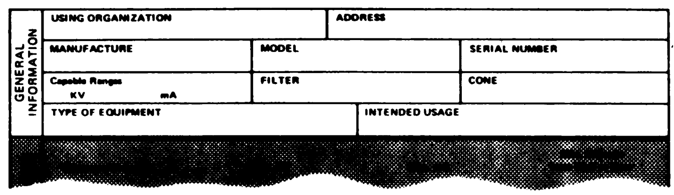
   a. Introduction

   In making a survey of an x-ray machine, several factors must be taken into consideration. The survey record form provides a means of systematically evaluating and recording the different aspects of an x-ray survey.

   The form has spaces for information on its front and back. The front side contains general information, approved ranges, operating limitations, monitoring devices, certification and a distribution list (for the front side).

   The back of the form contains information of interest to the radiological safety officer. This information is filed by the radiation protection office and is not distributed as is the front side. The information recorded on the back is the mR/hr measurements observed, personnel protection devices required, remarks and layout of the installation.

| L4 | RADIOGRAPHY SURVEY | 11 |
|---|---|---|


CERTIFICATION OF RADIATION GENERATING EQUIPMENT IN ASSIGNED FACILITY

| GENERAL INFORMATION | | | |
|---|---|---|---|
| | USING ORGANIZATION | ADDRESS | |
| | MANUFACTURE | MODEL | SERIAL NUMBER |
| | Capable Ranges KV mA | FILTER | CONE |
| | TYPE OF EQUIPMENT | INTENDED USAGE | |

4. Radiography Survey Form (contd.)

   b. General Information

   Different types of general information are recorded on the survey record in the block entitled General Information. The following information is required:

   USING ORGANIZATION. In this space, the company or division of the company is recorded.

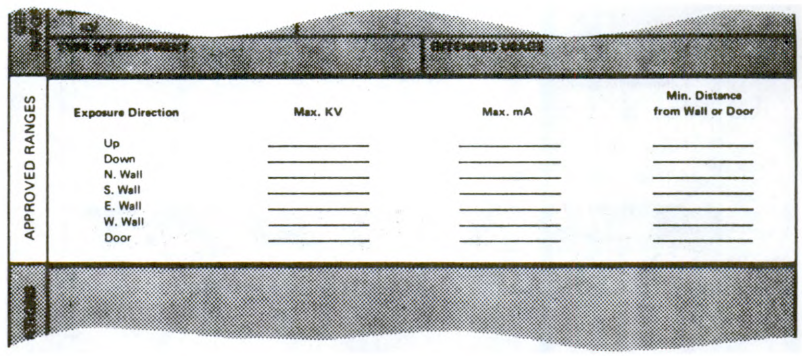
   ADDRESS. This is the address of the company or business. Enough information should be supplied so that someone familiar with the location, could find the source.

   TYPE OF EQUIPMENT. This refers to whether the x-ray source is a medical x-ray unit, scientific x-ray unit, or baggage search unit.

   INTENDED USAGE. This is the purpose for which the source is used. For example, chest x-ray, inspection of parts or baggage, x-ray diffraction, etc.

   MANUFACTURE-MODEL-SERIAL NUMBER-OTHER. This information identifies the x-ray source as to manufacturer, the model number, the serial number, and any other general information unique to the source. The CAPABLE RANGES of KV (kilovolt) and mA (milliamp) are noted. The FILTER material and thickness is noted. The CONE parameters are also recorded.

| L4 | RADIOGRAPHY SURVEY | 12 |
|---|---|---|



APPROVED RANGES

| Exposure Direction | Max. KV | Max. mA | Min. Distance from Wall or Door |
|---|---|---|---|
| Up | | | |
| Down | | | |
| N. Wall | | | |
| S. Wall | | | |
| E. Wall | | | |
| W. Wall | | | |
| Door | | | |

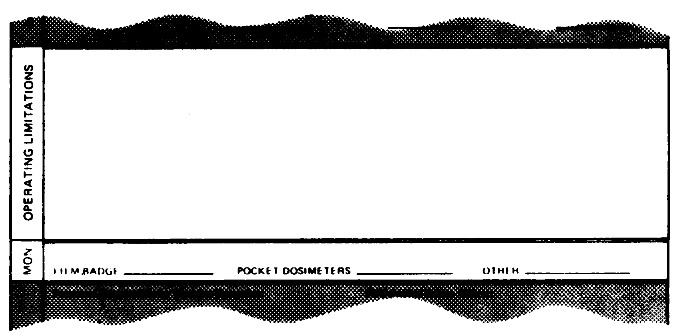
4. Radiography Survey Form (contd.)

   c. Approved Ranges

   The approved ranges of operating voltage and current are determined for various positions of the x-ray source. This is accomplished by pointing the source to a location and noting the source position with respect to that location. The accelerating voltage and current are then increased until the highest safe radiation levels are noted outside the shielded walls.

   Each pertinent source orientation listed under EXPOSURE DIRECTION is checked. The resulting MAX KV (maximum kilovolts) and MAX mA (maximum milliamp) are listed in the respective columns. The MIN. DIST. FROM WALL OR DOOR is noted for the particular source orientation. These kilovolt and milliamp settings are the maximum approved ranges permitted for the x-ray source for the orientations described.

| L4 | RADIOGRAPHY SURVEY | 13 |
|---|---|---|




4. Radiography Survey Form (contd.)

   d. Operating Limitations

   The OPERATING LIMITATIONS are enumerated on the survey form. Operating limitations might be:

   1) mode of operation restriction

   2) workload restriction

   3) restrictions on occupancy of adjacent areas

   4) restrictions on training and authorization of operating personnel.

   5) restrictions on allowed source orientations

   6) requirements of warning signs

   7) maximum weekly exposure time

   8) safety device and interlock requirements

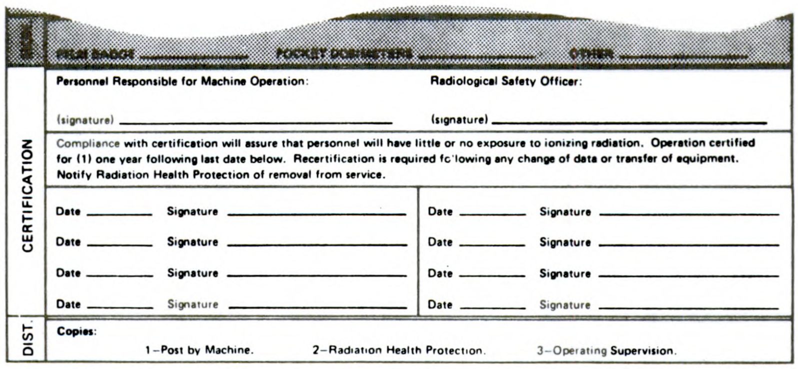
   9) proper electrical grounding

   10) any other prerequisite to safe operation pertinent to a particular x-ray source.

   e. Monitoring Devices

   The monitoring devices (MON) required to be worn by operating personnel are also listed. Such devices may be a FILM BADGE, POCKET DOSIMETER, or some OTHER device such as a finger ring.

| L4 | RADIOGRAPHY SURVEY | 14 |
|---|---|---|



FILM BADGE ______ POCKET DOSIMETERS ______ OTHER ______

CERTIFICATION

Personnel Responsible for Machine Operation:

(signature) ____________

Radiological Safety Officer:

(signature) ____________

Compliance with certification will assure that personnel will have little or no exposure to ionizing radiation. Operation certified for (1) one year following last date below. Recertification is required fc'lowing any change of data or transfer of equipment. Notify Radiation Health Protection of removal from service.

| | |
|---|---|
| Date ______ Signature ____________ | Date ______ Signature ____________ |
| Date ______ Signature ____________ | Date ______ Signature ____________ |
| Date ______ Signature ____________ | Date ______ Signature ____________ |
| Date ______ Signature ____________ | Date ______ Signature ____________ |

DIST.

Copies:

1–Post by Machine. 2–Radiation Health Protection. 3–Operating Supervision.

4. Radiography Survey Form (contd.)

f. Certification

The certification entails the signing of the survey form by the PERSONNEL RESPONSIBLE FOR MACHINE OPERATION, the RADIOLOGICAL SAFETY OFFICER, and the monitor who performed the survey (SURVEYED BY).

If the x-ray source is not altered, recertification is acknowledged by inserting a DATE and SIGNATURE (of the monitor performing the recertification).

Certification is for one year providing no alteration of the X-ray source and no changes in operating procedure are made.

g. Distribution

Distribution of front side of the survey form is as follows:

1) Machine posting

2) Radiation Health Protection Files

3) Operating Supervision

| L4 | RADIOGRAPHY SURVEY | 15 |
|---|---|---|

MEASUREMENTS

INSTRUMENT USED

| | North Wall | South Wall | East Wall | West Wall |
|---|---|---|---|---|
| Certified KV | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Certified KV + 10 | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Maximum Operating KV | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Shielding Material | ______ | ______ | ______ | ______ |
| Shielding Thickness | ______ | ______ | ______ | ______ |
| Occupancy Factor | ______ | ______ | ______ | ______ |
| Use Factor | ______ | ______ | ______ | ______ |

| | Floor | Ceiling | Door(s) | Other |
|---|---|---|---|---|
| Certified KV | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Certified KV + 10 | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Maximum Operating KV | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Shielding Material | ______ | ______ | ______ | ______ |
| Shielding Thickness | ______ | ______ | ______ | ______ |
| Occupancy Factor | ______ | ______ | ______ | ______ |
| Use Factor | ______ | ______ | ______ | ______ |

SAFETY DEVICES

4. Radiography Survey Form (contd.)

   h. Measurements

   The back of the survey form is used for information of interest to the radiation protection office.

   First the INSTRUMENT USED to perform the survey is recorded. For example, Technical Associates CP-5, Victorian 440, etc. Measurements in mR/hr are made at the NORTH WALL, SOUTH WALL, EAST WALL, WEST WALL, FLOOR, CEILING, DOOR(S) and OTHER possible areas of leakage. The maximum reading observed at a particular location is recorded. These readings are made for the CERTIFIED KV, CERTIFIED KV + 10 and MAXIMUM OPERATING KV. Also the SHIELDING MATERIAL, SHIELDING THICKNESS, OCCUPANCY FACTOR, and USE FACTOR are noted for each of the measurement positions. The occupancy factor is the percentage of time during the week that personnel occupy a given area around the x-ray source. The use factor is the percentage of time during the week that the source is used in the particular orientation. Special attention is given to: door sills and jambs, door locks, electrical fixtures in walls (the effective wall thickness is less), pipe holes, ducts, louvers, glassed areas (common glass may be substituted for Pb glass following breakage), sky-shine and the operator's position.

| L4 | RADIOGRAPHY SURVEY | 16 |
|---|---|---|

**PERSONNEL PROTECTION**

SAFETY DEVICES

Lights ______ Door Interlocks ______ Signs { HV ______ X-RAY ______

Alarm ______ Emergency Exit System ______

Electrical Grounding ______ Time Indicator ______ Emergency Shut-off ______

**REMARKS AND LAYOUT**

REMARKS AND LAYOUT

4. Radiography Survey Form (contd.)

   i. Personnel Protection

   The personnel protection devices in use are noted. Safety devices might be LIGHTS, ALARMS, ELECTRICAL GROUNDING, DOOR INTERLOCKS, EMERGENCY EXIT SYSTEM, exposure TIME INDICATOR, high voltage (HV) or X-RAY warning SIGNS, or an EMERGENCY SHUT-OFF system inside the x-ray room.

   j. Remarks and Layout

   Remarks should designate the areas where dose is excessive under any practicable operating conditions. (The maximum permissible limit is 100 mr/wk for controlled areas, and 10 mr/wk for uncontrolled areas). The remarks should also list any deficiencies in the safety devices.

   A layout of the x-ray installation is sketched in the space provided. The position of the source, doors, operator and other personnel are noted. Also the dose/wk is noted at personnel locations.

STUDENTS' LABORATORY EXERCISE

1. **PHASE I. SURVEY OF AN X-RAY INSTALLATION**
2. **PHASE II. EFFECT OF VARIATION OF MACHINE PARAMETERS**

## C. STUDENTS' LABORATORY EXERCISE

### 1. Introduction

The students' laboratory exercise will be conducted in two phases. In Phase I a survey of an x-ray unit will be made. Measurements will be taken and results reported on a survey form.

During Phase II the students will vary the operating parameters to observe the effect on beam intensity. The high voltage, current and filter will be varied.

2. Phase I. Survey of an X-Ray Installation

   a. Preparation

      1) The class should divide into four teams with a team leader elected from each team.

      2) The team leader will be the person who asks questions of the operator and makes measurements. Other members of the team will make observations and record data.

      3) Each team member will fill out a survey record form. Discussion with other team members is encouraged.

      4) The findings of each team will be discussed at the conclusion of the lab.

   b. X-Ray Machine Survey

      1) Fill in the General Information block of the X-Ray Survey Form in Figure 18.

      2) Determine the approved ranges for operation. Fill in the Approved ranges section of the survey form.

      3) Determine the personnel protection devices in use by checking the appropriate spaces on the Personnel Protection block of Figure 19.

      4) Next fill in the Remarks and Layout section of the survey form.

      5) Make measurements using the CP-5 and complete the measurements block in Figure 19.

      6) List the operating limitations that should be imposed on the x-ray installation. Record limitations on the survey form in the space provided for these comments.

      7) Check the monitoring devices that should be worn by x-ray machine operators.

      8) Certify the survey form by otaining the appropriate signatures.

## CERTIFICATION OF RADIATION GENERATING EQUIPMENT IN ASSIGNED FACILITY

**GENERAL INFORMATION**

| | | |
|---|---|---|
| USING ORGANIZATION | ADDRESS | |
| MANUFACTURE | MODEL | SERIAL NUMBER |
| Capable Ranges<br>KV mA | FILTER | CONE |
| TYPE OF EQUIPMENT | INTENDED USAGE | |

**APPROVED RANGES**

| Exposure Direction | Max. KV | Max. mA | Min. Distance from Wall or Door |
|---|---|---|---|
| Up | | | |
| Down | | | |
| N. Wall | | | |
| S. Wall | | | |
| E. Wall | | | |
| W. Wall | | | |
| Door | | | |

**OPERATING LIMITATIONS**

**MON.**

FILM BADGE ____________ POCKET DOSIMETERS ____________ OTHER ____________

**CERTIFICATION**

Personnel Responsible for Machine Operation:

(signature) ____________

Radiological Safety Officer:

(signature) ____________

Compliance with certification will assure that personnel will have little or no exposure to ionizing radiation. Operation certified for (1) one year following last date below. Recertification is required following any change of data or transfer of equipment. Notify Radiation Health Protection of removal from service.

| | | | |
|---|---|---|---|
| Date ______ | Signature ____________ | Date ______ | Signature ____________ |
| Date ______ | Signature ____________ | Date ______ | Signature ____________ |
| Date ______ | Signature ____________ | Date ______ | Signature ____________ |
| Date ______ | Signature ____________ | Date ______ | Signature ____________ |

**DIST.**

**Copies:**

1—Post by Machine. 2—Radiation Health Protection. 3—Operating Supervision.

## MEASUREMENTS

**INSTRUMENT USED**

| | North Wall | South Wall | East Wall | West Wall |
|---|---|---|---|---|
| Certified KV | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Certified KV + 10 | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Maximum Operating KV | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Shielding Material | ______ | ______ | ______ | ______ |
| Shielding Thickness | ______ | ______ | ______ | ______ |
| Occupancy Factor | ______ | ______ | ______ | ______ |
| Use Factor | ______ | ______ | ______ | ______ |

| | Floor | Ceiling | Door(s) | Other |
|---|---|---|---|---|
| Certified KV | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Certified KV + 10 | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Maximum Operating KV | ______ mR/hr | ______ mR/hr | ______ mR/hr | ______ mR/hr |
| Shielding Material | ______ | ______ | ______ | ______ |
| Shielding Thickness | ______ | ______ | ______ | ______ |
| Occupancy Factor | ______ | ______ | ______ | ______ |
| Use Factor | ______ | ______ | ______ | ______ |

## PERSONNEL PROTECTION

**SAFETY DEVICES**

Lights ______ Door Interlocks ______ Signs { HV ______ X-RAY ______

Alarm ______ Emergency Exit System ______

Electrical Grounding ______ Time Indicator ______ Emergency Shut-off ______

## REMARKS AND LAYOUT

**REMARKS AND LAYOUT**

| mA | r/hr |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |

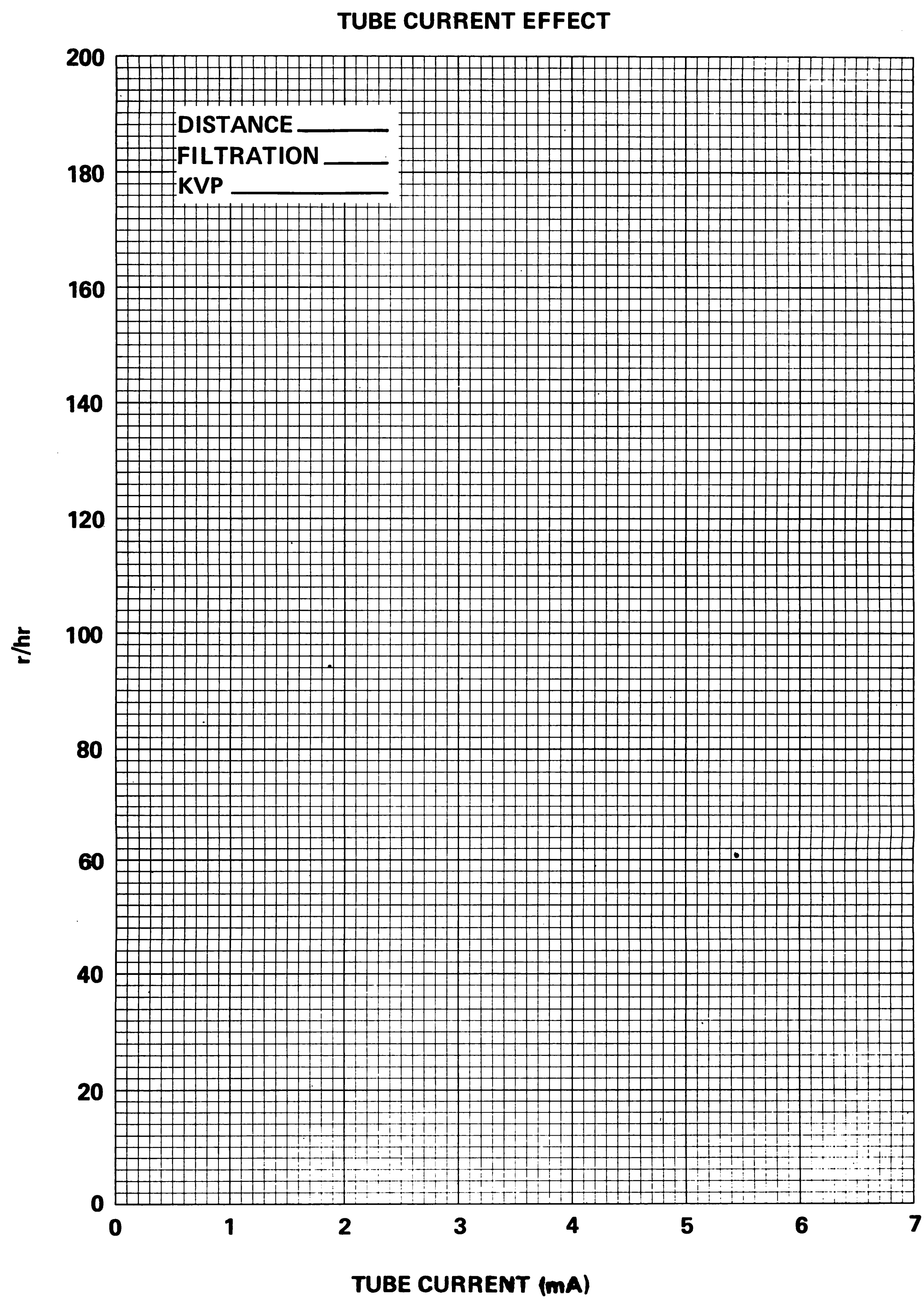
3. Phase II. Variation of Machine Parameters

a. Tube Current

1) Support the cutie pie on ring stand 72" from the tube target. Turn selector switch to the 250 r/hr scale and adjust zero. Set x-ray unit to operate at 75 kvp with no filtration, or under such other conditions as the instructor may direct.

2) Keeping all factors constant except mA, record dose rate at 1 mA intervals from 1 to 7 mA.

3) Graph data on Figure 21. In this and subsequent parts of the exercise, repeat any reading which seems to be questionable.


TUBE CURRENT EFFECT
DISTANCE ______
FILTRATION ______
KVP ______
200
180
160
140
120
100
80
60
40
20
0
r/hr
0
1
2
3
4
5
6
7
TUBE CURRENT (mA)

## IV. RADIOGRAPHY SURVEY

A. INTRODUCTION
1. Objectives
2. Overview
3. Equipment
4. Precautions

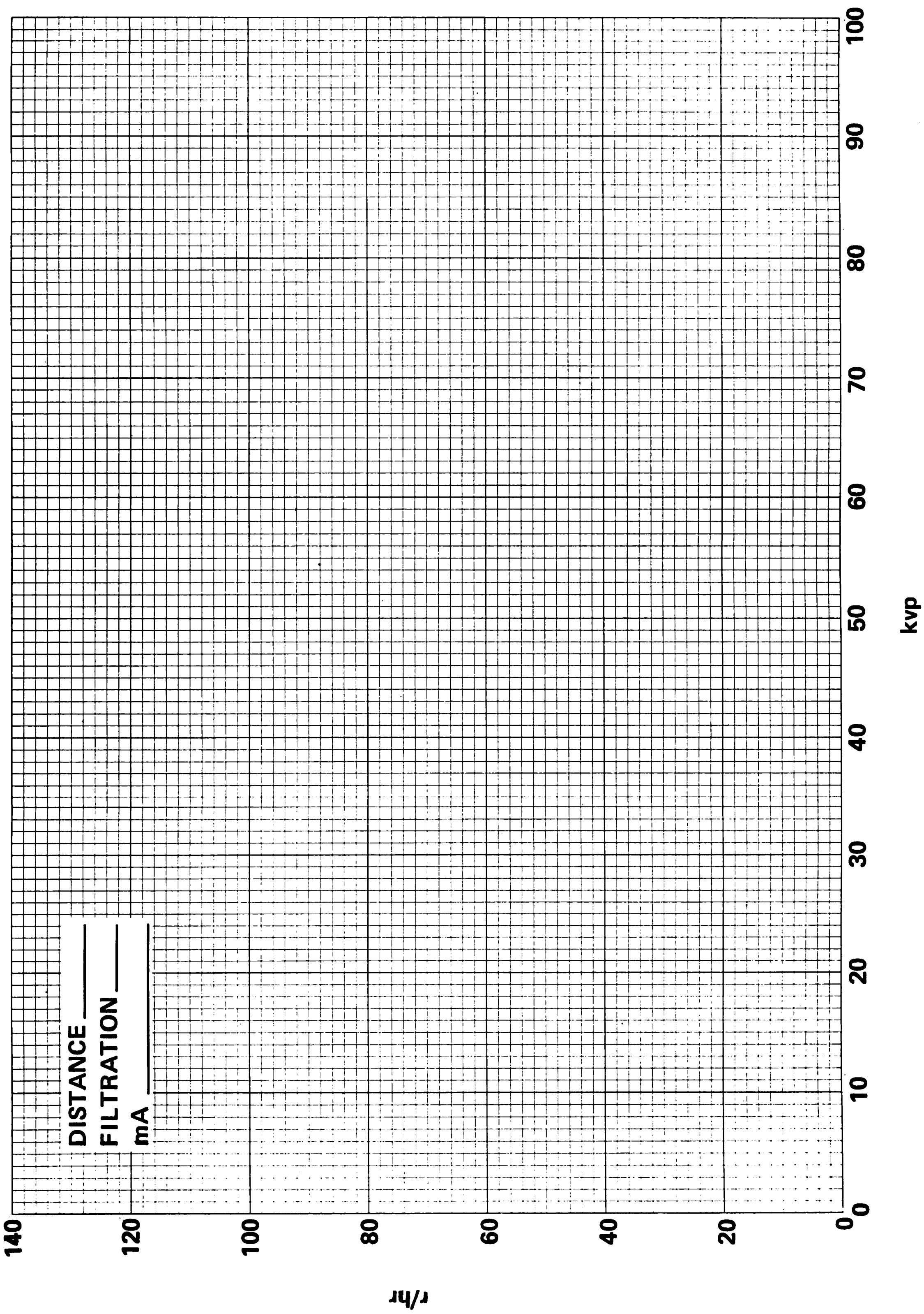
B. INSTRUCTOR'S DEMONSTRATION–LECTURE
1. Introduction
2. Production of X-Rays
3. Effects of Tube Parameters on X-Ray Spectra
4. Radiography Survey Form

C. STUDENT'S LABORATORY EXERCISE
1. Introduction
2. Phase I. Survey of an X-Ray Installation
   a. Preparation
   b. X-Ray Machine Survey
3. Phase II. Variation of Machine Parameters

**Slide L4-21**

   a. Tube Current
   b. Tube Voltage
   c. Filtration

## TUBE VOLTAGE EFFECT



| mm Al | 50 kvp r/hr | 100 kvp r/hr |
|---|---|---|
| 0 | | |
| 0.5 | | |
| 1.0 | | |
| 1.5 | | |
| 2.0 | | |

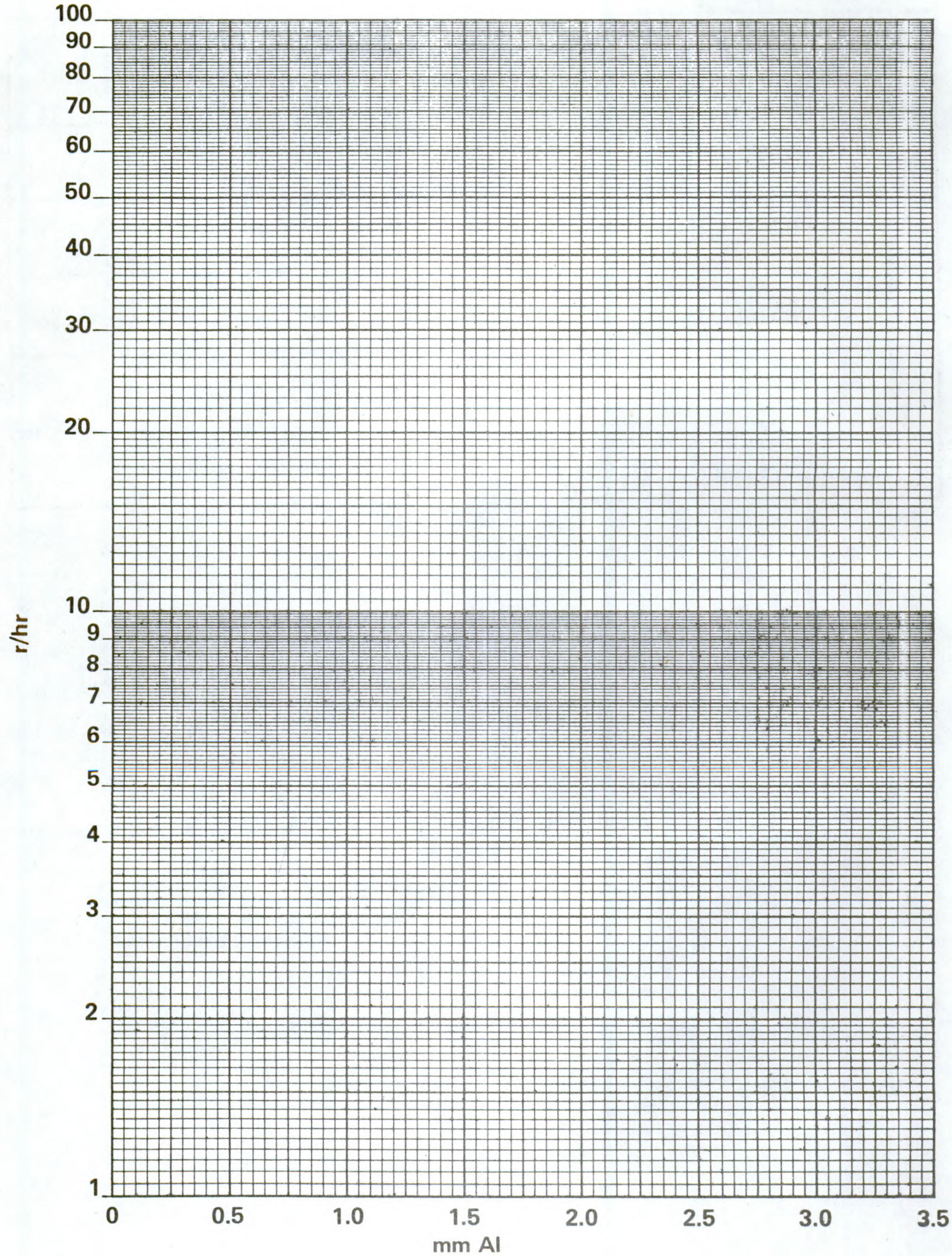
c. Filtration

1) Operate the tube at 50 kvp and 4 mA. Record the dose rate at 72" with 0.5 mm increments of aluminum filtration.

2) Repeat the above at 100 kvp and 4 mA.

3) Draw both absorption curves on the same semilogarithmic graph sheet on Figure 25.

## FILTRATION EFFECT






*USGPO: 1984-760-911-5016